



# Beyond Ethanol: A Comprehensive Review of the Nutritional, Microbiological and Functional Potential of Traditional Alcoholic Beverages

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**Abstract.** For thousands of years, the role of traditional alcoholic drinks has been more than just to be consumed; rather, they have been a part of human culture with many functions. This literature review is focused on the cause beneath the health benefits of traditionally fermented alcoholic drinks by first using Indian beverages and then expanding globally. Studies show that when individuals consume these beverages moderately, they are able to obtain true health benefits. The health benefits of consuming traditionally fermented alcoholic beverages stem from bioactive compounds formed through fermentation as well as from probiotic microorganisms, antioxidants and essential nutrients that are created through this same process. This literature review provides current scientific information of the health benefits of traditionally fermented alcoholic beverages; however, the review also acknowledges the need for moderate consumption of such beverages.

**Keywords:** Rice-based fermented Alcoholic beverages, Traditional alcohol, Nutritional benefits, Probiotics, Health properties, Medicinal uses, Micronutrients.

## 1 Introduction

Humans have been creating alcoholic beverages and consuming them for thousands of years using a method called fermentation which is also one of the earliest forms of food preservation by humans [1]. Fermented beverages created from traditional recipes are the result of a miraculous process where microorganisms convert simple ingredients into completely new products; during this conversion process, beneficial compounds are formed that can support human health [2]. The World Health Organization acknowledged that traditional beverages play an essential part in cultural celebrations/social occasions and many of these drinks contain substances that could be therapeutically valuable [3]. Researchers have spent numerous years conducting studies on the association between alcohol consumption and health outcomes and have come to the same multi-dimensional conclusion [4]. While high amounts of alcohol use have a number of negative health implications moderate use

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of traditionally fermented beverages has also been shown to offer several health benefits as a result of its bioactive compounds, probiotics and antioxidants [5,6].

## 2 Traditional Alcoholic Beverages of India

### 2.1 Overview of Indian Traditional Fermented Beverages

India has a very large diversity of traditional fermented beverages which is reflected in over 350 documented major types of traditional beverages, where each type is made based on the use of the traditional knowledge of past generations [3]. The majority of these homemade alcoholic beverages are prepared locally, as well as being hand-made, by blending the local raw materials (predominantly rice or other grains) with local traditional yeast or bacteria starter cultures[3,7].The Indian Himalayan Region (IHR), comprising Himachal Pradesh, Uttarakhand, Jammu and Kashmir, Ladakh, , Arunachal Pradesh, Sikkim, Darjeeling hills and northern parts of Assam, hosts particularly rich traditions of beverage fermentation [3].

### 2.2 Alcohol Fermented Rice-Based Beverages (AFRBs) from North-East India

#### 2.2.1 Types and Preparation Methods

For decades people in North-East India made alcohol fermented rice-based beverages (AFRBs). These beverages are also an important part of their spiritual and cultural traditions where they use them to celebrate important events or ceremonies within their community [8]. To make these beverages there is a very complex fermentation process. This process involves a mixture of microbial communities from a starter cake along with many different medicinal plants [8,9].The starter cakes, which are known as 'marcha' in Sikkim, 'hamei' in Manipur and 'amao' in Bodo communities, serve as mixed inocula containing yeasts, lactic acid bacteria (LAB) and molds [8,10].

#### 2.2.2 Prominent North-Eastern Rice Beverages

**Apong:** Prepared by the Mishing and other tribes of Arunachal Pradesh, Apong exists in two primary varieties - Poro Apong and Nugin Apong. Research has demonstrated that rice beer varieties contain alcoholic content ranging from 9.41 to 19.33% [v/v], with significant antioxidant properties. Tests shows the free radical scavenging activity against DPPH radicals varied from 1.94–4.14 mg of ascorbic acid/ml and for ABTS radicals it is 1.69–3.91 mg of ascorbic acid/ml which reflects how well these beverages neutralize harmful free radicals. The drinks also contain phenolic compounds ranging from 2.07 to 5.40 mg gallic acid per mL of rice beer [11].

**Xaaj:** A traditional rice beer of Assam prepared using glutinous rice and starter cultures. When bacterial composition was analysed using modern genetic sequencing

techniques (16S rDNA), 18 different types of bacteria were found. Most notably, lactic acid bacteria dominate, making up about 90% of all bacteria found in the beverage [11].

**Judima:** The Dimasa, Kachari tribe of Assam and Nagaland produces Judima, a rice-based alcoholic drink that traditional healers believe can address various health issues. According to traditional medicine practices, drinking appropriate amounts of Judima may help with jaundice, diarrhea, cholera, urinary problems and digestive disorders [12].

**Jou/Joubishi:** An essential part of the socio-cultural life of the Bodo people, prepared from fermented cooked rice with locally produced yeast cake known as Amao [10]. The traditional preparation uses seven plant species including *Scoparia dulcis*, *Oryza sativa*, *Artocarpus heterophyllus*, *Musa paradisiaca*, *Clerodendrum infortunatum*, *Ananas comosus* and *Plumbago zeylancia* [10].

### 2.2.3 Health Benefits of North-Eastern Rice Beverages

Traditional healthcare systems in North-Eastern India have long used these AFRBs to address several health concerns like digestion problems, tiredness, diabetes and hypertension [8]. Modern scientific investigation reveals that due to use of medicinal plants and micro flora, these beverages are enriched with medicinal benefits [8,9].

**Probiotic Content:** Strains of *Lactobacillus* and *Pediococcus* species improve bile and gastric juice tolerance, address hyperlipidemia, diabetes, obesity and possess amyolytic activities while regulating the expression of fatty acid biosynthetic genes [9]. *Saccharomyces* strains decrease the secretion of pro-inflammatory cytokines and alter respective mRNA expression [9].

**Gut Health Benefits:** Roseburia is a very special bacterium which has been shown to enhance gut health and improve overall digestion by producing butyric acid; a short chain fatty acid that can help with maintaining immune function and reducing inflammation. Researchers are looking into using the presence of Roseburia as a possible marker for several health problems such as irritable bowel syndrome, allergies, obesity and type 2 diabetes [12].

**Antioxidant Properties:** Phenolic compounds and flavonoids give these beverages high levels of antioxidants, helping to protect against oxidative stress-related illnesses [11].

## 2.3 Traditional Alcoholic Beverages of Other Indian Regions

### 2.3.1 Tribal Beverages of Central and Eastern India

**Bonda Beverages:** The Bonda people of Odisha have produced over 23 types of traditional alcoholic beverages for many years. These beverages are used in the social and cultural functions of their community and provide income to families [13]. These

beverages are divided into categories by the main ingredient and method of preparation of the beverage which includes both fermentation and distillation [13].

**Haria:** Haria is a low alcohol fermented beverage that contains *Bifidobacterium* species and is commonly found in central and northeastern India [14]. Similar beverages are also commonly found in the Himalayas and are referred to as "Chhang" [14].

### 2.3.2 South Indian Fermented Beverages

**Neera:** Neera is a sugary, natural fluid extracted from the sap of the coconut tree. It is known to ferment naturally when it sits out too long and is widely consumed throughout India. Researchers have identified lactic acid bacteria from Neera that have demonstrated strong probiotic properties, such as surviving in low pH environments, demonstrating hydrophobic cell surface properties of 50.32 to 77.8% and auto-aggregating at rates of 51.02 to 78.95%. Among those studied, *Lactobacillus brevis* MYSN 106 was found to exhibit superior probiotic characteristics, including ability to survive during gastrointestinal transit, ability to attach to surfaces and aggregate with other bacteria—two important features for beneficial bacteria to establish themselves in the GI tract [15].

## 2.4 Medicinal Plants and Starter Cultures in Indian Traditional Beverages

Many traditional alcoholic beverages contain medicinal herbs and plants which contribute health-promoting attributes (therapeutic) [9].

*Clerodendrum indicum* is an herb used in making starter cakes and has been found to possess bronchitis remedies and anti-inflammatory action; *Cissampelos pareira* is also used as an anti-malarial and wound-healing agent; *Cinnamomum glanduliferum* is a cold, cough remedy; *Vernonia cinerea* has anti-inflammatory and respiration disorder benefits and *Amomum aromaticum* has digestive and gastrointestinal system remedies [9].

The medicinal and nutritional values of the above mentioned plant extracts provide value added economic benefit to traditional alcoholic beverages [3]; process of fermentation increases the bioavailability of above mentioned compounds, allowing them to be easily absorbed by the body through drinking [8].

## 2.5 Microbiological Composition and Probiotic Properties

### 2.5.1 Dominant Microbial Consortia

Traditional Indian fermented beverages have complex microbial populations and metagenomic analysis found that there was a high prevalence of Proteobacteria, Actinobacteria, Firmicutes and Bacteroides present at the highest level of abundance across all tribal preparations [16].

Lactic Acid Bacteria were predominant, specifically *Lactobacillus* and *Pediococcus* species [11,15].

### 2.5.2 Probiotic Mechanisms and Benefits

Presence of probiotic lactic acid bacteria in traditional Indian fermented drinks, have many features that can contribute to health:

**Survival Ability In Gastrointestinal Tract:** The survival rates of lactic acid bacteria in acidic environments [pH 2-3] and bile salts [4-6% NaCl] indicates their ability to colonize [15,17].

**Antimicrobial Activity:** Many probiotic lactic acid bacteria produce antibacterial compounds such as organic acids, H<sub>2</sub>O<sub>2</sub> and proteins known as *bacteriocins*. Research shows they can inhibit common disease-causing bacteria like *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Klebsiella pneumonia*, *Salmonella typhimurium* and even the fungus *Candida albicans* [18].

**Immune Modulation:** Probiotics occupy binding sites on the mucosa that would otherwise allow harmful bacteria to bind, thereby competing with pathogens and helping to modulate the immune response of the host [19]. Probiotics aid in lactose metabolism, produce lactate ion from lactic acid and manufacture vitamins [19].

**Metabolic Health:** Consuming traditional fermented beverages containing probiotics regularly has been linked to reduced risk of developing type II diabetes, better metabolic control (i.e., better insulin sensitivity) and promoting weight loss [20,21].

## 2.6 Nutritional Composition of Indian Traditional Beverages

Presence of proteins, carbohydrates, crude fibre, macro- and micronutrients make traditional fermented beverages incredibly nutritional. These nutritional values increase by fermentation via:

- Breaking down complex carbohydrates into simpler, more digestible forms
- Increasing vitamin content, particularly B-complex vitamins
- Enhancing mineral bioavailability
- Producing essential amino acids and peptides
- Generating bioactive compounds with health-promoting properties [8,22]

## 3 Traditional Alcoholic Beverages from Other Countries

### 3.1 East Asian Rice Wines

#### 3.1.1 Japanese Sake

Sake is Japan's oldest fermented rice wine, whose fermentation process occurs in a single step (two-stage), during which starch conversion (saccharification) and ethanol

fermentation take place simultaneously [23]. This fermentation process produces bioactive compounds, i.e. amino acids, peptides and kojic acid, with diverse health-related benefits [23,24].

**Cardiovascular Benefits:** The occurrence of lactic acid bacteria, especially *L. mesenteroides var sake* and *Lactobacillus sake* in traditional sake preparation methods, enhances the quality of the fermentation process [26]. A 2018 study published in *Nutrients* found moderate consumption associated with reduced heart disease risk in Japanese men, attributed to alcohol and polyphenols present in sake [25].

**Bioactive Compounds:** Ferulic acid, a known antioxidant found in sake, has the ability to help enhance the effectiveness of other antioxidants [27]. The antimicrobial and skin-brightening properties of Kojic acid produced during fermentation have been researched extensively [25,28]. Research indicates that kojic acid inhibits melanin production which results in anti-aging effects [28,29].

**Digestive Health:** The enzyme content in sake aids digestion, while its relatively low acidity compared to other alcoholic beverages makes it gentler on the stomach [27,30]. Traditional sake contains probiotics including *Lactobacillus* species that promote gut health [30,31]. The enzyme content in sake helps with digestion. In comparison to many other types of alcoholic drinks, sake is relatively low in acidity making it easier on the stomach [27,30]. The probiotic content in traditional sake, including *Lactobacillus species*, promotes gut health [30,31].

**Amino Acids and Peptides:** Sake is rich in beneficial peptide and amino acid content which supports muscle repair, immune system function and general well-being [28,32].  
**Prevention of Cancer and Other Diseases:** The amino acid and peptide content in sake may also contribute to decreasing the risk of certain ailments like hypertension and cancer [32].

**Antioxidant Properties:** Chinese rice wine exhibits significant antioxidant activity based on DPPH, ABTS and FRAP assay results due to high amounts of phenolic compounds, Maillard reaction products, amino acids, proteins, gamma-aminobutyric acid, minerals, oligosaccharides and vitamins [33]. Rice wine has been proven to stop or slow down the onset of various diseases, which includes cancer, cardiovascular disease, diabetes, atherosclerosis and aging [33].

### 3.1.2 Korean Rice Wines

Makgeolli and Cheongju, traditional Korean rice wines, contain live cultures that support gut health [34]. Unfiltered versions of rice wine, like makgeolli, are rich in probiotics and contain essential nutrients, including vitamin **B**, magnesium and selenium [34].

## 3.2 European Fermented Beverages

### 3.2.1 Kefir

Kefir is a milk-based fermented drink prepared from kefir grains which are a blend of beneficial bacteria and yeast. Kefir has been called "the yogurt of the 21st Century", because of the numerous health advantages associated with consuming it [35].

**Microbial Components:** Kefir consists of an assortment of microorganisms including *Lactobacillus*, *Leuconostoc*, *Acetobacter* and several yeast species. These microorganisms function as biochemical factories to produce valuable nutrients with potential anticancer and antimicrobial properties [35, 37].

**Nutritional Profile:** A one-cup serving of kefir prepared using low-fat dairy milk, contains around 30% of the suggested daily calcium intake, 10% of the daily Vitamin A need, 25% of the daily Vitamin D requirement and 11 grams of protein. Additionally, kefir is a resource of vitamins B and Tryptophan, an amino acid that helps combat stress [38, 39].

**Cardiovascular Advantages:** A polysaccharide in kefir called Kefiran has been shown to lower cholesterol levels and blood pressure [38]. In addition to demonstrating the ability to alter the microbial components of the gut, research indicates that consumption of kefir can positively affect the gastrointestinal tract [35, 37].

**Lactose Intolerance:** Since most of the lactose found in milk is consumed during the fermentation process, many people who are lactose intolerant may be able to consume kefir without experiencing symptoms related to lactose intolerance [38, 40].

**Probiotic characteristics:** Due to the high concentration of lactic acid bacteria contained in kefir, it may provide additional probiotic characteristics when compared to some other types of fermented beverages; LAB help to regulate the contents of the GI tract and maintain them in a healthy state [41]. Randomized clinical trials have confirmed that traditional kefir (not water kefir) has demonstrated efficacy in treating lactose malabsorption and aiding in the elimination of *H. pylori* [42].

### 3.2.2 Red Wine

Extensive research has been conducted on red wine as a result of the numerous health benefits it provides to the cardiovascular system due to its high concentration of polyphenols [43],[44],[45].

**Polyphenolic Composition:** A glass of red wine contains:

- Approximately 200 milligrams (mg) of total polyphenols. White wine is known to contain only about 30 mg [46]
- Polyphenol composition includes 5–8%
- Dimer procyanidins-10–15%
- Catechins- 5–10%
- Anthocyanidins, 3–6%
- flavonols, <0.3%
- phenolic acids, <1%

- resveratrol
- 60–80% polymeric polyphenols [46].

**Resveratrol and Cardiovascular Protection:** Resveratrol is one type of polyphenol found in red wine, as well as in some types of grapes. It has a number of biochemical and physiological properties that are beneficial to overall health, such as being estrogenic, having antiplatelet activity and possessing anti-inflammatory properties [47]. Researchers have also shown that modest in-take of red wine has the ability to reduce cardiovascular disease and mortality by 30% to 50% [43].

**Mechanisms of Cardioprotection:** Due to polyphenols, wine exert protective effects through multiple mechanisms:

- Reduction in LDL oxidation and atherosclerosis progression [43,44]
- Reducing in inflammatory responses by Inhibiting nuclear factor-kappa B [NF- $\kappa$ B], [43]
- Increased HDL cholesterol levels providing protection against coronary vascular events [43,48]
- Reduced platelet aggregation through effects on prostanoid synthesis and nitric oxide mediation [43,49]
- Enhanced fibrinolytic activity and reduced fibrinogen levels [43,50]

**Antioxidant and Anti-inflammatory Effects:** Polyphenols shows antioxidant activity by scavenging free radicals and possess anti-apoptotic and pro-angiogenic properties [43]. Research shows that resveratrol reduces malondialdehyde (MDA) and infarct size in isolated rat hearts subjected to ischemia/reperfusion injury [44,51].

**Metabolic Benefits:** Moderate consumption of red wine has been associated with reduced incidence of diabetes and improved insulin sensitivity [49,52]. Studies have shown that individuals who consume red wine regularly have lower fasting glucose concentrations and reduced rates of diabetes incidence than those who do not drink red wine [49].

### 3.3 Asian Tea-Based Fermented Beverages

#### 3.3.1 Kombucha

The symbiotic culture of bacteria and yeast (SCOBY) used to ferment sweetened tea to make kombucha [53,54]. Consumption of Kombucha has been growing globally due to its worldwide commercially availability as a low-alcohol functional beverage [53,55].

**Microbial Composition:** The SCOBY contains many different types of living bacteria and yeast that work together as biochemical factories to produce amino acids, polyphenols, organic acids, enzymes, antibiotic substances, and vitamins [35,54].

**Antimicrobial Properties:** Kombucha exhibits antibacterial activity against *S. aureus*, *S. dysenteriae*, *V. cholerae*, *S. typhi*, *E. coli*, *S. typhimurium* and *B. cereus* [56]. Both black and green tea kombuchas contain antifungal compounds that are effective against *Candida* yeasts and pathogenic fungi such as *A. niger*, *Aspergillus flavus* and *Microsporiumgypseum* [56].

**Bioactive Compounds:** Both the tea base and metabolites created by the SCOBY (i.e., organic acids and enzymes), contribute to the bioactivity of kombucha. Bioactivity refers to efficacy of these compounds to reduce oxidative stress and the count of free radicals present in the body, which can promote general health and wellness [57].

**Health Benefits:** Research suggests kombucha supports gut health, reduces oxidative stress, aids detoxification and strengthens immune function [57]. Studies demonstrate higher fermentation period increase both antioxidant capacity and content of bioactive compound [58].

## 4 Lactic Acid Bacteria: Central to Health Benefits

### 4.1 Global Significance of LAB in Fermented Beverages

Lactic acid bacteria represent the most significant group of probiotic organisms commonly used in fermented products worldwide [59,60]. Lactic acid is produced during fermentation by non-spore-forming, Gram-positive, non-pathogenic bacteria “LAB” [61].

### 4.2 Health Benefits of LAB

#### 4.2.1 Gastrointestinal Health

Probiotics from *Lactobacillus* genus naturally occurs in fermented foods and can prevent diseases caused by gastrointestinal tract pathogens by maintaining proper intestinal flora [19,62]. LAB improve nutrition, soothe intestinal disorders, improve immune system, optimize gut ecology and promote overall wellbeing through their ability to compete with harmful bacteria for attachment sites and by modulating the host's immune response [19,63].

#### 4.2.2 Prevention of Chronic Diseases

Lactic acid bacteria found in fermented drinks lowers the prevalence of diabetes and obesity and can help prevent cancer [20]. Probiotic bacteria improve the intestinal microbiota's composition, prevent constipation, boost immunity, stop intestinal pathogens from growing and lessen lactose intolerance symptoms [20,64].

#### 4.2.3 Metabolites and Bioactive Compounds

LAB produces an extensive spectrum of metabolites, which include organic acids, vitamins, enzymes, exopolysaccharides, antimicrobial peptides (bacteriocins) and bioactive compounds [61,65]. These metabolites have major health advantages, improve food flavor and help preserve food [61].

**Bacteriocins:** Antimicrobial peptides produced by LAB exhibit broad-spectrum antimicrobial activity useful as food bio-preservatives [18,61].

**Short-Chain Fatty Acids [SCFAs]:** Probiotics and their metabolites help maintain gut barrier, regulate mood, reduce inflammation, support immune system and maintain energy homeostasis [66].

**Vitamins and Essential Nutrients:** LAB contribute to synthesis of B vitamins and enhance mineral bioavailability through fermentation [22,61].

### 4.3 LAB from African Fermented Traditional Foods

African fermented traditional foods and drinks contain lactic acid bacteria, which have been identified as promising sources of new probiotics [67]. These LAB exhibit positive health effects, strong antimicrobial activity and resistance to gastrointestinal disorders [68,69].

According to studies on fermented traditional foods and drinks from Ethiopia (Cabbage-Shamita, Bukuri, Ergo, Kotcho, Borde and Bulla). LAB has a high potential for probiotics [68]. Under stressful conditions, such as, intestinal inhibitory substances, low pH, bile salts and simulated gastric/intestinal juice, isolates showed tolerance [68]. Common bacterial and fungal pathogens were antagonistically affected by these LAB [68].

## 5 Bioactive Compounds and Their Mechanisms

### 5.1 Antioxidants in Traditional Beverages

Antioxidants found in traditional fermented drinks shield cells from harm brought on by free radicals. [29,30,33]. Antioxidants found in these beverages include:

**Polyphenols:** Compounds including flavonoids, phenolic acids, stilbenes (resveratrol), anthocyanins and tannins, neutralize free radicals, promoting overall health and well-being [30,43,46,70].

**Ferulic Acid:** and Ferulic acid (forms from rice as a by-product of fermentation) can enhance the effectiveness of other antioxidants [27,33].

**Melanoidins:** Produced through Maillard reactions during fermentation, contribute to the antioxidant capability [33].

**Kojic Acid:** Specific to sake and rice wines, provides antioxidant and antimicrobial properties [25,28].

### 5.2 Peptides and Amino Acids

During fermentation process, proteins transformed into bioactive peptides and amino acids which have multiple physiological functions [23,27,32].

**Muscle Repair and Growth:** Amino acids act as precursors to the formation of creatine and collagen to help build new muscle mass and repair damaged muscles [27,32].

**Anti-inflammatory Effects:** As per studies Amino acids possess anti-inflammatory properties and support the development of connective tissue [27].

**Immune Function:** Research suggests specific amino acids, like glutamine and arginine, may inhibit the growth of tumors and support an individual's immune response [27].

**Cardiovascular Health:** Peptide compounds can stimulate the production of natural killer cells to support an individual's immune function and cardiovascular health. [30].

### 5.3 Vitamins and Minerals

Fermented beverages contain vitamins and minerals that are beneficial to health:

**Vitamin B:** Plays vital role in healthy nerve functioning and energy production [29,34].

**Minerals:** Including selenium, phosphorus, copper, calcium, zinc, potassium, magnesium [31,34].

**Vitamin Synthesis:** Fermentation enhance vitamins content and its available to the body (bioavailability) [8,22].

## 6 Cardiovascular Health Benefits: A Detailed Examination

### 6.1 Mediterranean Diet and The French Paradox

The French paradox is a phenomenon where people eat diets that include high amounts of saturated fats, yet have fewer cases of heart disease than other developed countries. This phenomenon is largely due to their moderate wine consumption [71] as part of the Mediterranean diet [71], which has proven to be effective at lowering CVD rates by modifying a person's overall cardiovascular risk profile by reducing inflammation and increasing antioxidants in the body [71].

### 6.2 Mechanisms of Cardiovascular Protection

**Lipid Profile Modification:** Moderate consumption will increase levels of HDL cholesterol and reduce the oxidation of LDL cholesterol [43,48]. With each gram of alcohol that is consumed per day, an individual's HDL will increase by 0.004 mmol/L [43].

**Platelet Function:** Polyphenols found in traditional beverages will inhibit platelet aggregation by affecting prostanoid synthesis from arachidonate and by causing an increase in nitric oxide mediated mechanisms [43,49].

**Endothelial Function:** Activation of endothelial nitric oxide synthase by wine polyphenols improves vascular function and blood flow [72].

**Inflammatory Response:** Inhibition of NF- $\kappa$ B reduces inflammatory responses associated with atherosclerosis development [43].

**Thrombosis Prevention:** Increasing fibrinolytic activity and reducing fibrinogen levels decreases the risk of developing thrombosis [43,50].

### 6.3 Clinical Evidence

There are numerous epidemiological studies, case-control studies and prospective trials that demonstrate cardiovascular health benefits from moderate consumption of traditional beverages:

- Cardiovascular morbidity and mortality can be reduced by 30-50% with moderate consumption [43].
- Moderate consumption can significantly reduce the risk of myocardial infarction [48].
- Moderate consumption decrease the risk of ischemic stroke by reducing platelet aggregation [27].
- Improved insulin resistance and metabolic syndrome parameters [49,52]

## 7 Cancer Prevention Potential

### 7.1 Mechanisms of Cancer Prevention

Research suggests compounds in traditional fermented beverages may possess anti-cancer properties through multiple mechanisms:

**Gamma-oryzanol:** Found in rice bran and rice oil, may help prevent growth of certain cancer cell types [29].

**Resveratrol:** Demonstrates chemoprevention capabilities through antioxidant and anti-inflammatory pathways [47].

**Anthocyanins:** Particularly malvidin-3-O-glucoside, shows tumor cell inhibition properties [73].

### 7.2 Epidemiological Evidence

The epidemiologic literature reports a 57 percent decrease in lung cancer risk and a 50 percent decrease in prostate cancer risk as a result of moderate red wine (polyphenol) intake [43]. It is also important to understand that excessive alcohol consumption will increase cancer risk. Therefore, moderate consumption is essential.

## 8 Gut Microbiome and Immune Function

### 8.1 Microbiome Modulation

Traditional fermented beverages contain live microbes which can both modify the gut microbiota composition and its functions [35,66,74]. The gut microbiota has many critical functions for overall health. Some of these include:

- Nutrient metabolism and absorption
- Immune system development and function
- Protection against pathogens
- Mental wellbeing through gut-brain axis communication [30]

## 8.2 Immune System Support

**Barrier Function:** Probiotic bacteria enhance the production of the components of the intestinal lining including *mucin* and *immunoglobulin A* (IgA) [27].

**Pathogen Exclusion:** LAB inhibit pathogenic bacteria from attaching to the intestinal epithelium by competing for attachment sites and producing antimicrobial compounds [19,61].

**Immune Cell Stimulation:** Certain peptides stimulate the proliferation of Natural Killer cells which play an important role in eliminating infections [30].

**Anti-inflammatory Effects:** SCFAs produced by probiotics support immune function and help to regulate inflammation [12,66].

## 9 Metabolic Health and Diabetes Prevention

### 9.1 Insulin Sensitivity

There is evidence suggesting that moderate amounts of alcohol, especially red wine, may contribute to a reduced incidence of type II diabetes and better insulin sensitivity [49,52]. Red wine drinkers have been shown to have lower fasting blood sugar levels than abstinent individuals and a lower incidence of diabetes [49].

### 9.2 Obesity Management

*Pediococcus* and *Lactobacillus* species have been identified to regulate hyperlipidemia, diabetes and obesity while controlling the genes expression involved in the production of fatty acids [9]. LAB in fermented beverages has been demonstrated to reduce the incidence of obesity [20].

### 9.3 Metabolic Syndrome

Certain components of metabolic syndrome are positively impacted by Moderate consumption which includes:

- Blood pressure reduction [38]
- Cholesterol management [27,38]
- Glucose regulation [49,52]
- Body weight management [9,20]

## **10 Safety Considerations and Optimal Consumption**

### **10.1 Importance of Moderation**

The traditional fermented beverages offer health benefits, but these benefits can only be achieved through moderate consumption patterns [4,25,29,30]. When taken in excess (beyond moderation) alcohol consumption poses several serious health hazards, including:

- Liver damage and cirrhosis
- Amplified cancer risk
- Cardiovascular problems including hypertension
- Neurological damage
- Addiction and alcohol use disorders

### **10.2 Moderate Consumption**

Research suggests optimal protective effects (for type 2 diabetes) occur at:

- Approximately 22 gram a day for men and Approximately 24 gram a day for women [49]

Consumption exceeding 60 g/day for men and 50 g/day for women becomes harmful [49].

### **10.3 Quality and Preparation Standards**

Maximization of health benefits can be achieved through:

- Using traditional preparation techniques to ensure diverse population of beneficial microbes in the beverage.
- Using pure ingredients free from adulterants
- Proper fermentation conditions
- When possible, consume fresh, unsterilized products.
- Following proper food sanitation/hygiene guidelines when preparing beverages [13].

### **10.4 Populations Requiring Special Consideration**

Certain groups should be especially caution or abstain from alcohol consumption, including:

- Pregnant and breastfeeding women
- Individuals with alcohol use disorders or family history
- Those taking medications that interact with alcohol
- Individuals with certain medical conditions like pancreatitis ,liver disease.
- Minors under legal drinking age

## 11 Future Research Directions

### 11.1 Gaps in Current Knowledge

Even though there are growing evidence for health benefits, but certain areas need further attention:

**Standardization:** There is limited clinical data regarding the ideal amount and specific strain of probiotics in traditional beverages [42,75].

**Safety Studies:** Additional researches are need to evaluate the safety of consuming traditional beverages in vulnerable populations such as the elderly, immunocompromised and medically ill individuals [42].

**Mechanistic Studies:** Detailed investigations into molecular mechanisms of action for specific bioactive compounds [8,75].

**Comparative Effectiveness:** Systematic comparisons between traditional and modern fermented products [42].

### 11.2 Commercialization Potential

Traditional beverages possess significant potential for commercial development [3,8].

Factors supporting commercialization include:

- Growing consumer interest in functional foods
- Potential economic benefits for rural communities
- Preservation of traditional knowledge and cultural heritage
- Development of probiotic products from indigenous strains

### 11.3 Technological Improvements

Future research should focus on:

- Characterization of specific probiotic strains and their properties
- Optimization of fermentation conditions for bioactive compound production
- Development of standardized starter cultures
- Quality control measures ensuring consistency and safety
- Shelf-life extension while maintaining probiotic viability

## 12 Conclusion

Many aspects of bioactive compounds, probiotics, antioxidants and nutrients found in traditional alcoholic fermented beverages contribute to human health when consumed responsibly (in moderation). There are a large number of fermented rice based beverages throughout North Eastern India which contain both a large number of medicinal plants and a variety of bioactive compounds that promote health, due to their unique and diverse microbial consortia.

Similar examples include, globally recognized fermented drinks like sake, kombucha, kefir and red wine that have demonstrated scientifically-documented health profits in terms of dropping the threat of heart ailments, improving metabolism, enhancing digestion and increasing immunity.

These fermented beverages achieve their health benefits through the synergy between multiple bioactive compounds, including; the probiotic effects of lactic acid bacteria, the antioxidant effects of polyphenols and other compounds that protect cells from oxidative stress, the physiologic functions supported by peptides and amino acids and the anti-inflammatory/immunomodulatory effects of bioactive compounds generated during fermentation.

However, it is significant to underline that the health benefits of fermented beverages will only be achieved if they are consumed at moderate or reasonable amounts. Over-consumption of alcohol can negate the potential health benefits of fermented beverages and pose serious health risks. Future studies should focus on the development of standards for production and commercialization, developing an understanding of the mechanisms behind the health benefits of fermented beverages, conducting safety evaluations of fermented beverages in diverse populations and developing methods for sustainable commercialization of fermented beverages while preserving traditional knowledge and maintaining product quality and safety. Fermented beverages represent an interesting intersection of food, culture and medicine that deserve further scientific study and careful consideration of incorporation into modern dietary recommendations. In addition to contributing to public health, studying fermented beverages may also aid in preserving cultural heritages and supporting indigenous communities around the world.

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