

Understanding the Chemistry, Bioactive Components, and Health Implications of Kashmiri Salt Tea (Noon Chai) -A Critical Review

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Abstract: Kashmiri Salt Tea, commonly known as Noon Chai, is a traditional beverage that occupies a central place in the cultural, social and dietary practices of Kashmir. Unlike conventional tea preparations, Noon Chai is prepared by boiling green tea leaves with sodium bicarbonate and salt, followed by the addition of milk, resulting in a characteristic pink-colored beverage with a distinctive taste and chemical composition. The unique preparation process induces a series of physicochemical transformations that influence the beverage's sensory properties, nutritional profile and biological activity. Growing scientific interest in functional foods and traditional beverages has highlighted the need for a comprehensive evaluation of Noon Chai from the perspectives of food chemistry, nutrition and public health. This review critically examines the chemistry of Kashmiri Salt Tea, emphasizing the role of tea polyphenols, catechins, flavonoids, amino acids, minerals and milk-derived nutrients. Particular attention is given to the chemical reactions responsible for color formation, the influence of alkaline processing on phytochemical stability and the interactions between tea constituents and milk proteins. The review further explores the potential health benefits associated with antioxidant, anti-inflammatory, cardioprotective, metabolic and neuroprotective activities of tea-derived bioactive compounds while considering concerns related to excessive sodium intake. By integrating evidence from contemporary literature, this review aims to provide a scientific framework for understanding the health implications of Noon Chai and to identify future research priorities that may help preserve its cultural significance while promoting evidence-based dietary recommendations.

Keywords: Antioxidants; Bioactive Compounds; Health Implications; Kashmiri Salt Tea; Noon Chai

INTRODUCTION

Tea is among the most widely consumed beverages worldwide and has been an integral component of human diets for centuries. Derived from the leaves of *Camellia sinensis*, tea is consumed in numerous forms, including green tea, black tea, oolong tea, white tea and fermented tea preparations. The global popularity of tea is attributable not only to its sensory appeal but also to its rich composition of bioactive compounds that have been associated with various health benefits [1–5].

Among the diverse tea traditions of the world, Kashmiri Salt Tea, popularly known as Noon Chai, represents a distinctive beverage characterized by its unique ingredients, preparation method and cultural significance. Unlike conventional sweetened tea beverages, Noon Chai is prepared using green tea leaves, sodium bicarbonate (NaHCO_3), salt, water and milk. The resulting beverage possesses a characteristic pink color, creamy texture and mildly salty taste that distinguishes it from other tea preparations [6,7].

The consumption of Noon Chai is deeply embedded within the socio-cultural fabric of Kashmir. It is traditionally consumed during breakfast and throughout the day, particularly during the harsh winter months when hot beverages serve as an important source of warmth and comfort. The beverage is commonly accompanied by traditional bakery products such as girda, kulcha, lavasa and baqerkhani, forming an essential component of the Kashmiri dietary pattern. Beyond its nutritional role, Noon Chai functions as a symbol of hospitality, community interaction and cultural identity [8,9].

Scientific interest in traditional foods and beverages has increased considerably owing to the growing recognition of their potential functional and nutraceutical properties. Green tea, the principal ingredient in Noon Chai, contains a wide range of biologically active compounds, including catechins, flavonoids, phenolic acids, alkaloids, amino acids and minerals. Numerous studies have demonstrated that these compounds possess antioxidant, anti-inflammatory, antimicrobial, cardioprotective, neuroprotective and anti-diabetic properties [10–18]. However, the chemistry of Noon Chai differs substantially from that of conventional green tea because of its unique preparation process. The addition of sodium bicarbonate creates alkaline conditions that promote oxidation, polymerization and structural transformation of tea

polyphenols. Furthermore, the incorporation of milk introduces proteins, fats, minerals and lactose that interact with tea-derived compounds and potentially influence their bioavailability and physiological effects [19–23].

Despite its widespread consumption across Kashmir and neighboring regions, Noon Chai remains relatively understudied in scientific literature. Most investigations concerning tea-related health benefits focus on green tea or isolated tea polyphenols, while studies specifically examining Kashmiri Salt Tea are scarce. Given the increasing prevalence of hypertension and cardiovascular disease, concerns regarding sodium intake have also intensified, making it essential to evaluate both the potential benefits and risks associated with regular consumption of Noon Chai [24–29].

The present review aims to critically evaluate current knowledge regarding the chemistry, bioactive components, nutritional composition and health implications of Kashmiri Salt Tea. By synthesizing evidence from food chemistry, nutrition and public health research, the review seeks to provide a comprehensive scientific understanding of this culturally significant beverage.

Historical and Cultural Significance of Noon Chai

Traditional foods and beverages often serve as repositories of cultural memory and collective identity. Noon Chai occupies such a position within Kashmiri society, where it has been consumed for centuries and continues to represent an important element of everyday life. Historical evidence suggests that salted tea traditions originated in Central and East Asia and spread through trade routes connecting Tibet, China, Central Asia and the Kashmir Valley. Over time, these traditions evolved in response to local climatic conditions, food habits and cultural preferences, ultimately giving rise to the distinctive Kashmiri preparation known today as Noon Chai [30].

The term “Noon” is derived from the Kashmiri word for salt, reflecting one of the beverage's defining ingredients. In some regions, the beverage is also referred to as Sheer Chai, where “sheer” denotes milk, emphasizing another essential component of the preparation. Although variations exist across households and communities, the core ingredients and preparation techniques have remained largely unchanged across generations [31].

Noon Chai occupies a prominent place in Kashmiri domestic life. It is traditionally served during breakfast and frequently accompanies freshly baked breads prepared in local bakeries. During winter, when temperatures in many parts of Kashmir fall below freezing, the beverage provides warmth and contributes to daily caloric intake. In rural areas, it has historically served as an important source of hydration and nourishment for individuals engaged in agricultural and outdoor labor [32]. The social significance of Noon Chai extends beyond nutrition. Serving tea is widely regarded as a gesture of hospitality and respect toward guests. Family gatherings, social meetings, weddings, religious occasions and community events commonly feature Noon Chai as a central element of social interaction. Its preparation and sharing reinforce cultural continuity and communal bonds [33].

Interestingly, similar salted milk tea traditions are observed in Tibet, Mongolia, Nepal and parts of Central Asia, suggesting a common historical origin. Nevertheless, the Kashmiri version possesses unique characteristics, particularly its distinctive pink color and elaborate brewing process, which differentiate it from related beverages consumed elsewhere [34].

In the contemporary era, despite increasing urbanization and changing dietary preferences, Noon Chai remains deeply embedded within Kashmiri cultural identity. Its continued popularity underscores the importance of scientifically evaluating this traditional beverage while preserving the cultural heritage associated with its consumption.

Ingredients and Traditional Preparation Process

The unique sensory and chemical characteristics of Noon Chai arise from a combination of carefully selected ingredients and a specialized brewing process that differs substantially from conventional tea preparation. Traditionally, Noon Chai is prepared using green tea leaves, water, sodium bicarbonate, salt and milk. Additional ingredients such as cardamom, cinnamon, almonds, pistachios, walnuts, or cream may be incorporated to enhance flavor and nutritional value depending upon household preferences and regional practices [35]. Green tea leaves constitute the primary source of bioactive compounds in the beverage. These leaves contain high concentrations of catechins, flavonoids, phenolic acids, caffeine, amino acids and minerals. Milk contributes proteins, fats, lactose, calcium, phosphorus and vitamins, while salt and sodium bicarbonate influence flavor and facilitate important chemical transformations during brewing [19,20].

Traditional preparation begins with prolonged boiling of green tea leaves in water. Sodium bicarbonate is added during this stage, creating an alkaline environment that promotes extraction and transformation of tea constituents. Continuous heating, stirring and aeration gradually convert the tea liquor into a concentrated reddish extract. In many households, small quantities of cold water are periodically added during boiling to intensify color development and enhance extraction efficiency [22]. Following concentration of the tea extract, milk and salt are added. The addition of milk transforms the reddish concentrate into the characteristic pink beverage associated with Noon Chai. The final product possesses a creamy consistency, mildly salty flavor and distinctive aroma that are highly valued by consumers. The prolonged brewing process significantly influences the beverage's chemical composition. Elevated temperatures, alkaline conditions and repeated aeration induce oxidation and polymerization reactions among tea polyphenols, generating compounds not

typically present in conventional green tea infusions. Consequently, Noon Chai represents a chemically distinct beverage rather than merely a salted version of green tea [21,23].

Chemistry of Kashmiri Salt Tea

The chemistry of Noon Chai is remarkably complex and reflects interactions among tea polyphenols, milk proteins, salts, minerals and alkaline agents. These interactions influence color, flavor, antioxidant activity and nutritional properties. Green tea leaves contain more than 700 identified chemical compounds, including polyphenols, alkaloids, amino acids, carbohydrates, proteins, lipids, vitamins, pigments and minerals [1,19,20]. Among these constituents, polyphenols are the most abundant and biologically significant.

The major catechins present in green tea include epigallocatechin gallate (EGCG), epicatechin gallate (ECG), epigallocatechin (EGC) and epicatechin (EC). These compounds contribute substantially to the antioxidant properties of tea and have been associated with numerous physiological benefits [11,18,23]. A distinctive feature of Noon Chai preparation is the use of sodium bicarbonate. Upon heating, sodium bicarbonate decomposes and increases the alkalinity of the brewing medium. This elevated pH alters the stability of catechins and promotes oxidation, epimerization and polymerization reactions. Such transformations contribute significantly to the beverage's unique appearance and chemical profile [22,26].

One of the most visually striking features of Noon Chai is its characteristic pink color. Initially, prolonged boiling under alkaline conditions generates a dark reddish-brown concentrate. During this process, tea polyphenols undergo oxidation, producing pigmented compounds analogous to the theaflavins and thearubigins found in black tea. Upon addition of milk, interactions between these pigments and milk proteins, combined with light scattering by fat globules, create the characteristic pink coloration [21,27].

The addition of milk introduces further chemical complexity. Casein and whey proteins can bind tea polyphenols through hydrogen bonding and hydrophobic interactions. These interactions may influence antioxidant activity, sensory properties and gastrointestinal absorption of bioactive compounds. Although some studies suggest that milk reduces measurable antioxidant activity in vitro, other investigations indicate that many beneficial effects remain biologically relevant following digestion and metabolism [28,29].

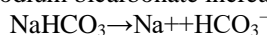
Component	Representative Compound	Molecular Formula	Significance in Noon Chai
Polyphenols	Epigallocatechin Gallate (EGCG)	C ₂₂ H ₁₈ O ₁₁	Major antioxidant in green tea
Polyphenols	Epicatechin (EC)	C ₁₅ H ₁₄ O ₆	Contributes to antioxidant activity
Polyphenols	Epigallocatechin (EGC)	C ₁₅ H ₁₄ O ₇	Influences color and bioactivity
Alkaloids	Caffeine	C ₈ H ₁₀ N ₄ O ₂	Provides stimulant effects
Amino Acids	L-Theanine	C ₇ H ₁₄ N ₂ O ₃	Responsible for umami taste
Milk Proteins	Casein	Protein polymer	Interacts with tea polyphenols
Salts	Sodium Chloride	NaCl	Characteristic salty taste
Alkaline Agent	Sodium Bicarbonate	NaHCO ₃	Produces the characteristic pink-red color
Minerals	Calcium	Ca ²⁺	Present in milk and influences stability
Minerals	Magnesium	Mg ²⁺	Present in tea leaves

The chemistry of Noon Chai therefore represents a dynamic interplay among thermal processing, alkaline reactions, oxidation pathways and protein–polyphenol interactions. Understanding these processes provides the foundation for evaluating the beverage's nutritional and health-related properties, which are discussed in subsequent sections.

Important Chemical Reactions in Noon Chai

1. Alkalinization of Tea Polyphenols

The addition of sodium bicarbonate increases pH:



Under alkaline conditions, catechins and other polyphenols undergo oxidation and polymerization, producing reddish pigments that contribute to the characteristic pink color of Noon Chai.

2. Polyphenol–Protein Complex Formation

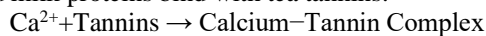


These complexes influence:

- Color stability
- Astringency
- Antioxidant bioavailability

3. Milk-Tea Interaction

Calcium ions and milk proteins bind with tea tannins:



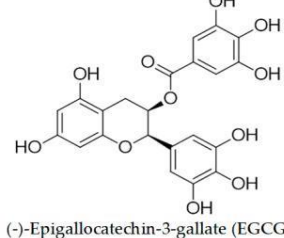
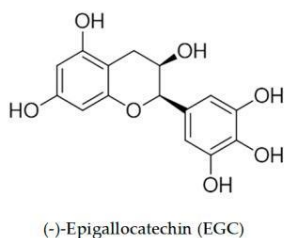
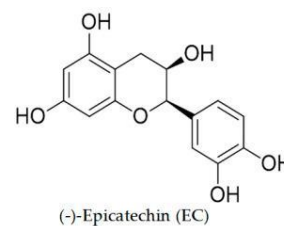
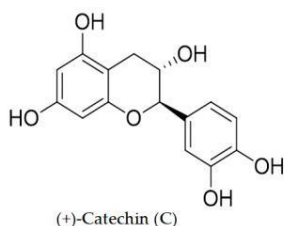
This reduces bitterness and modifies flavor.

Bioactive Components of Kashmiri Salt Tea

The nutritional and functional significance of Kashmiri Salt Tea is primarily derived from the diverse array of bioactive compounds naturally present in green tea leaves and, to a lesser extent, from nutrients contributed by milk. Although the traditional preparation process involves prolonged heating and alkaline treatment, that may alter the concentration and structure of some phytochemicals, substantial quantities of biologically active compounds remain in the final beverage. These compounds are responsible for many of the physiological effects traditionally associated with tea consumption and have attracted considerable scientific attention because of their potential roles in disease prevention and health promotion [36–40]. Among the numerous phytochemicals present in tea, catechins constitute the most abundant and extensively studied class of compounds. Green tea is particularly rich in catechins, including epigallocatechin gallate (EGCG), epicatechin gallate (ECG), epigallocatechin (EGC) and epicatechin (EC). These polyphenolic molecules possess strong antioxidant properties owing to their ability to donate electrons and neutralize reactive oxygen species. Research conducted over the past two decades has demonstrated that catechins contribute significantly to the antioxidant, anti-inflammatory, antimicrobial, cardioprotective and anti-diabetic effects associated with tea consumption [18,36,41]. Among these compounds, EGCG is generally regarded as the most biologically active catechin. It has been extensively investigated for its capacity to modulate cellular signaling pathways involved in oxidative stress, inflammation, apoptosis and metabolism. Recent studies indicate that EGCG influences gene expression, mitochondrial function and immune responses, thereby contributing to protection against chronic diseases such as cardiovascular disorders, obesity, type 2 diabetes and certain cancers [37–40]. Although the alkaline conditions employed during Noon Chai preparation may induce partial degradation of native EGCG molecules, oxidation products generated during the brewing process may retain substantial antioxidant activity and continue to contribute to the beverage's biological properties [36].

In addition to catechins, tea contains a broad spectrum of flavonoids, including quercetin, kaempferol and myricetin. These compounds exhibit diverse biological activities and contribute to the overall antioxidant capacity tea. Flavonoids function by scavenging free radicals, chelating transition metals and modulating intracellular signaling pathways associated with inflammation and cellular responses. Their synergistic interactions with catechins further enhance the functional value beverages [39–41].

The prolonged brewing and oxidation processes involved in Noon Chai preparation also facilitate the formation of larger polyphenolic structures resembling



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theaflavins and thearubigins, compounds commonly associated with black tea fermentation. These oxidation products contribute not only to the beverage's color and flavor but also to its antioxidant potential. Recent evidence suggests that theaflavins possess anti-inflammatory, antimicrobial, lipid-lowering and cardioprotective activities, expanding the spectrum of health-promoting compounds present in traditionally prepared Kashmiri Salt Tea [27,32].

Another important bioactive constituent of tea is L-theanine, a unique non-protein amino acid found almost exclusively in tea plants. L-theanine contributes to the characteristic flavor profile of tea and has been associated with numerous neurological and psychological benefits. Experimental and clinical studies have demonstrated that L-theanine promotes relaxation without causing sedation, improves attention and cognitive performance and may reduce psychological stress by influencing neurotransmitter systems within the central nervous system [33,37]. The combined presence of L-theanine and caffeine is believed to produce synergistic effects that enhance mental alertness while minimizing the overstimulation commonly associated with caffeine alone.

Tea also contains moderate concentrations of caffeine, together with smaller quantities of theobromine and theophylline. These methylxanthines contribute to the stimulant properties of tea and influence alertness, concentration and mood. Moderate caffeine consumption has been associated with improved cognitive function and reduced risk of certain neurodegenerative disorders. However, excessive intake may contribute to sleep disturbances, anxiety and cardiovascular

symptoms in sensitive individuals. Compared with many commercial tea and coffee beverages, Noon Chai generally contains moderate caffeine levels owing to its preparation from green tea leaves [33,42].

In addition to phytochemicals, tea leaves contain several essential minerals including potassium, magnesium, manganese, zinc, copper and calcium. Milk further enhances the mineral content of Noon Chai by contributing calcium, phosphorus and other micronutrients. These minerals support numerous physiological processes, including enzyme activity, cellular metabolism, nerve transmission and skeletal health. Although mineral concentrations vary depending upon tea cultivar, growing conditions and preparation methods, they contribute meaningfully to the beverage's nutritional profile [22,26].

The diverse bioactive constituents of Noon Chai create a chemically complex matrix that provides the basis for many of the health-related effects attributed to tea consumption. Understanding the interactions among these compounds is essential for evaluating the nutritional and therapeutic significance of this traditional beverage.

Nutritional Profile of Kashmiri Salt Tea

The nutritional composition of Noon Chai differs substantially from that of conventional tea because of the inclusion of milk, salt and sodium bicarbonate. While green tea itself contributes relatively few calories, the addition of milk increases the beverage's energy content and provides important macronutrients and micronutrients [22].

Milk serves as a valuable source of high-quality protein, supplying essential amino acids required for growth, tissue repair and physiological maintenance. Casein and whey proteins constitute the major protein fractions and contribute to both nutritional value and physicochemical interactions with tea polyphenols. Milk also provides varying amounts of lipids depending on the type and quantity of milk used during preparation. These fats contribute to flavor, texture, satiety and the absorption of fat-soluble nutrients [15,22]. Micronutrient contributions from milk are particularly noteworthy. Calcium, phosphorus, riboflavin, vitamin B12 and other nutrients present in milk play essential roles in skeletal health, neurological function and energy metabolism. Consequently, Noon Chai may provide greater nutritional value than plain tea infusions, particularly in populations where dairy products constitute an important dietary component [22,43].

Antioxidant Properties of Kashmiri Salt Tea

Oxidative stress arises from an imbalance between the generation of reactive oxygen species and the body's antioxidant defense mechanisms. Persistent oxidative stress contributes to cellular damage and plays a central role in the pathogenesis of numerous chronic diseases, including cardiovascular disorders, diabetes, cancer and neurodegenerative diseases [3,10]. Tea is widely recognized as one of the richest dietary sources of natural antioxidants. The antioxidant activity of tea is largely attributable to its polyphenolic constituents, particularly catechins and flavonoids. These compounds neutralize free radicals by donating electrons, thereby interrupting oxidative chain reactions and preventing damage to cellular components such as lipids, proteins and DNA [13,18,20].

In addition to direct free radical scavenging, tea polyphenols exhibit metal-chelating properties. By binding transition metals such as iron and copper, they reduce the formation of highly reactive hydroxyl radicals generated through Fenton-type reactions. Polyphenols also enhance endogenous antioxidant defenses by stimulating the activity of enzymes including superoxide dismutase, catalase and glutathione peroxidase [32,38].

The unique preparation process of Noon Chai raises important questions regarding the stability of antioxidant compounds under prolonged heating and alkaline conditions. Although certain catechins may undergo degradation during brewing, studies suggest that oxidation products formed during processing may retain significant antioxidant activity. Consequently, the overall antioxidant capacity of Noon Chai may remain substantial despite alterations in individual phytochemical concentrations [30,41].

Recent investigations employing advanced analytical techniques have confirmed that tea-derived polyphenols continue to exert biological antioxidant effects following digestion and metabolism. These findings suggest that antioxidant activity measured in laboratory assays may not fully reflect the physiological benefits observed in vivo [36,40].

Anti-inflammatory Properties

Chronic low-grade inflammation is increasingly recognized as a key factor underlying many major non-communicable diseases, including cardiovascular disease, diabetes mellitus, obesity, arthritis and neurodegenerative disorders. Consequently, dietary interventions capable of modulating inflammatory pathways have become an important area of nutritional research [39]. Tea polyphenols exert anti-inflammatory effects through multiple mechanisms. Experimental studies have demonstrated that catechins suppress the production of pro-inflammatory cytokines such as tumor necrosis factor- α , interleukin-1 β and interleukin-6. These cytokines play central roles in initiating and sustaining inflammatory responses within tissues [39,40]. A particularly important mechanism involves inhibition of nuclear factor-kappa B (NF- κ B), a transcription factor that regulates the expression of numerous inflammatory genes. By suppressing NF- κ B activation, tea catechins reduce the production of inflammatory mediators and contribute to improved cellular homeostasis [11,32].

The close relationship between oxidative stress and inflammation further amplifies the biological significance of tea polyphenols. Because oxidative stress promotes inflammatory signaling, the antioxidant activity of catechins indirectly

contributes to anti-inflammatory outcomes. Conversely, reductions in inflammation help limit oxidative damage, creating a mutually reinforcing protective effect [13,23].

Recent studies published in *Nutrients*, *Antioxidants* and *Food Chemistry* continue to support the role of tea-derived polyphenols in mitigating inflammatory processes associated with chronic disease development [38–40,41]. Although specific investigations focusing on Noon Chai remain limited, the presence of substantial quantities of tea-derived polyphenols suggests that similar mechanisms may operate in traditionally prepared Kashmiri Salt Tea.

The anti-inflammatory potential of Noon Chai therefore represents an important area for future investigation, particularly given the increasing prevalence of chronic inflammatory disorders worldwide.

Cardiovascular Health Implications of Kashmiri Salt Tea

Cardiovascular diseases (CVDs) remain the leading cause of mortality worldwide and account for a substantial proportion of the global burden of non-communicable diseases. Dietary factors play a pivotal role in cardiovascular health and among these, tea consumption has attracted considerable scientific attention because of its potential cardioprotective effects. The bioactive compounds present in green tea, particularly catechins and flavonoids, have been extensively investigated for their beneficial influence on vascular function, lipid metabolism, oxidative stress and inflammatory processes that contribute to cardiovascular disease development [42–45].

One of the most important mechanisms through which tea polyphenols exert cardiovascular benefits involves the improvement of endothelial function. The vascular endothelium plays a critical role in regulating blood vessel tone, blood flow, coagulation and inflammatory responses. Endothelial dysfunction is considered an early marker of atherosclerosis and cardiovascular disease. Experimental and clinical studies have demonstrated that tea catechins enhance nitric oxide bioavailability, improve vascular relaxation and reduce endothelial oxidative stress, thereby supporting normal cardiovascular function [28,42].

Tea polyphenols have also been associated with favorable effects on lipid metabolism. Several observational studies and meta-analyses suggest that regular tea consumption may contribute to reductions in total cholesterol, low-density lipoprotein (LDL) cholesterol and triglyceride levels while supporting overall lipid homeostasis. These effects are believed to arise from modulation of lipid absorption, enhancement of lipid metabolism and suppression of oxidative modification of LDL particles, a key event in the pathogenesis of atherosclerosis [32,41].

The antioxidant properties of tea-derived catechins further contribute to cardiovascular protection by reducing oxidative damage to vascular tissues. Oxidative stress promotes endothelial dysfunction, inflammation and plaque formation within arterial walls. By scavenging reactive oxygen species and enhancing endogenous antioxidant defenses, tea polyphenols help maintain vascular integrity and reduce cardiovascular risk [13,38].

Despite these potential benefits, the cardiovascular implications of Kashmiri Salt Tea require careful consideration because of its sodium content. Excessive sodium intake is a well-established risk factor for hypertension, stroke, coronary heart disease and chronic kidney disease. Global public health agencies, including the World Health Organization, consistently emphasize sodium reduction as a key strategy for preventing cardiovascular disease [43–47].

The health impact of Noon Chai therefore reflects a complex interaction between beneficial phytochemicals and dietary sodium. While tea-derived bioactive compounds may exert cardioprotective effects, excessive consumption of highly salted preparations may counteract some of these benefits, particularly among individuals with hypertension, cardiovascular disease, or increased salt sensitivity. Consequently, the overall cardiovascular consequences of Noon Chai consumption are likely to depend upon preparation practices, frequency of intake and broader dietary patterns.

Metabolic and Anti-Diabetic Effects

The global prevalence of obesity, metabolic syndrome and type 2 diabetes mellitus has increased dramatically during recent decades, prompting considerable interest in dietary interventions capable of improving metabolic health. Tea polyphenols have emerged as promising nutritional compounds because of their ability to influence glucose metabolism, insulin sensitivity, energy expenditure and body weight regulation [38,41,48].

Catechins, particularly EGCG, have been shown to modulate multiple molecular pathways involved in glucose homeostasis. Experimental studies suggest that these compounds enhance insulin signaling, improve glucose uptake by skeletal muscle and adipose tissue and reduce hepatic glucose production. Through these mechanisms, tea polyphenols may contribute to improved glycemic control and reduced risk of insulin resistance [37,38].

Another important mechanism involves the inhibition of digestive enzymes responsible for carbohydrate breakdown. By slowing the digestion and absorption of carbohydrates, tea polyphenols may attenuate postprandial blood glucose excursions and reduce metabolic stress on pancreatic β -cells. Such effects are particularly relevant in populations at risk of developing type 2 diabetes [32,38]. Research has also suggested that green tea catechins influence energy metabolism and body weight regulation. Studies indicate that catechins may enhance thermogenesis, increase fat oxidation and improve energy expenditure, thereby contributing modestly to weight management. Although the magnitude of these effects varies among individuals, regular tea consumption has frequently been associated with improved metabolic profiles and reduced risk of obesity-related disorders [41,48].

Recent investigations have further highlighted the role of tea polyphenols in reducing chronic low-grade inflammation associated with obesity and metabolic syndrome. By modulating inflammatory pathways and oxidative stress, tea-derived compounds may help prevent metabolic dysfunction and support long-term cardiometabolic health [39,40].

Although specific studies evaluating Noon Chai are limited, the presence of tea catechins and related polyphenols suggests that Kashmiri Salt Tea may share many of the metabolic benefits reported for green tea. However, the addition of milk, prolonged heating and alkaline processing may influence the stability and bioavailability of certain compounds, underscoring the need for targeted investigations focused specifically on this traditional beverage.

Gut Microbiota and Digestive Health

The human gastrointestinal tract hosts a highly diverse microbial ecosystem that plays a fundamental role in nutrition, metabolism, immune regulation and overall health. Growing evidence indicates that dietary polyphenols interact extensively with gut microorganisms, resulting in complex bidirectional relationships that influence both microbial composition and host physiology [36,40,49]. Tea polyphenols are only partially absorbed in the upper gastrointestinal tract. A substantial proportion reaches the colon, where they undergo biotransformation by intestinal microorganisms. During this process, microbial enzymes convert complex polyphenols into smaller bioactive metabolites that may exhibit enhanced biological activity and bioavailability. These metabolites contribute to many of the systemic health effects associated with tea consumption [36,49].

Emerging research suggests that tea polyphenols can act as prebiotic-like compounds by selectively promoting the growth of beneficial microbial populations. Increased abundance of genera such as *Bifidobacterium*, *Lactobacillus* and *Akkermansia* has been observed following regular consumption of polyphenol-rich diets. These microorganisms contribute to intestinal barrier integrity, immune regulation and metabolic health [25,36,40].

The gut microbiota also plays a critical role in regulating inflammatory responses. Beneficial microbial communities produce short-chain fatty acids and other metabolites that help maintain intestinal homeostasis and suppress chronic inflammation. By influencing microbial composition, tea polyphenols may indirectly support digestive and systemic health [49,50].

The traditional preparation of Noon Chai introduces additional factors that may affect gastrointestinal physiology. Milk proteins and lipids can interact with tea polyphenols, potentially altering their digestion and microbial metabolism. Furthermore, the beverage is often consumed with traditional Kashmiri breads and bakery products, creating a dietary context that may influence nutrient absorption and microbiota composition. These interactions remain poorly understood and represent an important area for future research.

Neurological and Cognitive Benefits

Tea has long been valued for its effects on mental alertness, concentration and psychological well-being. Modern scientific research increasingly supports these traditional observations and has identified several mechanisms through which tea-derived compounds influence brain function [33,37,51]. Caffeine is perhaps the most widely recognized neuroactive component of tea. By antagonizing adenosine receptors within the central nervous system, caffeine promotes wakefulness, enhances attention and reduces perceived fatigue. Moderate caffeine intake has consistently been associated with improved cognitive performance, particularly in tasks involving vigilance and sustained attention [33].

Unlike many caffeinated beverages, however, tea also contains significant quantities of L-theanine, an amino acid capable of crossing the blood-brain barrier. L-theanine influences neurotransmitter systems involving dopamine, serotonin and gamma-aminobutyric acid (GABA), promoting relaxation without sedation. Numerous studies suggest that the combination of caffeine and L-theanine produces synergistic effects that improve cognitive performance while reducing stress and anxiety [33,37]. Beyond these acute effects, tea polyphenols may contribute to long-term neurological health. Oxidative stress and chronic inflammation are recognized contributors to neurodegenerative disorders such as Alzheimer's disease and Parkinson's disease. The antioxidant and anti-inflammatory properties of catechins may therefore help protect neuronal tissues from age-related damage [37,52]. Recent studies have further suggested that tea polyphenols may influence neuronal signaling pathways, mitochondrial function and neuroplasticity. Although research remains ongoing, these findings indicate that regular tea consumption may contribute to cognitive resilience and healthy brain aging [52].

Given the widespread consumption of Noon Chai across generations in Kashmir, understanding its neurological implications represents an important avenue for future investigation.

Risks Associated with Excessive Sodium Intake

While the bioactive constituents of Kashmiri Salt Tea offer several potential health benefits, the beverage's sodium content remains a significant nutritional concern. Traditional preparation methods involve the addition of both sodium chloride and sodium bicarbonate, resulting in sodium concentrations that may contribute substantially to daily intake when consumed frequently [24,25]. Excessive sodium consumption has been consistently associated with elevated blood pressure and increased risk of cardiovascular disease. High sodium intake promotes fluid retention, increases vascular

resistance and contributes to structural changes within blood vessels and the kidneys. These physiological effects collectively increase the risk of hypertension, stroke, coronary artery disease, heart failure and chronic kidney disease [24,29,43–47].

The health implications of Noon Chai depend largely on the amount of salt added during preparation and the frequency of consumption. Occasional consumption as part of a balanced diet is unlikely to pose substantial risks for healthy individuals. However, habitual intake of multiple servings daily may contribute meaningfully to cumulative sodium exposure, particularly when combined with other salt-rich foods [53–57].

The available evidence therefore suggests that Kashmiri Salt Tea should be viewed as a nutritionally complex beverage possessing both beneficial and potentially adverse attributes. Its ultimate health impact is likely determined by the balance between its bioactive phytochemical content and its contribution to overall sodium intake.

Public Health Perspectives

Kashmiri Salt Tea (Noon Chai) occupies a unique position at the intersection of nutrition, culture and public health. Unlike many traditional foods that have gradually disappeared under the influence of globalization and changing lifestyles, Noon Chai continues to be consumed widely across urban and rural Kashmir. Its enduring popularity reflects not only its sensory appeal but also its deep-rooted association with cultural identity, hospitality and social interaction. Consequently, any evaluation of its health implications must consider both biomedical evidence and the broader socio-cultural context in which the beverage is consumed [56–60]. From a nutritional standpoint, Noon Chai presents an interesting paradox. On one hand, it contains numerous bioactive compounds derived from green tea that possess antioxidant, anti-inflammatory, cardioprotective and metabolic benefits. On the other hand, traditional preparation methods often involve relatively high amounts of sodium chloride and sodium bicarbonate, contributing to elevated dietary sodium intake. This duality highlights the importance of adopting a balanced perspective when assessing the public health implications of the beverage.

The burden of non-communicable diseases in India has increased substantially over recent decades. Hypertension, cardiovascular disease, diabetes mellitus and chronic kidney disease now represent major public health concerns across the country. Epidemiological studies indicate that excessive sodium consumption remains a significant contributor to the prevalence of hypertension and related cardiovascular complications [35,43–47]. Within this context, dietary practices associated with high salt intake warrant careful examination.

Several surveys conducted in India have demonstrated that average sodium consumption frequently exceeds recommended levels established by national and international health agencies. While no large-scale epidemiological studies have specifically quantified the contribution of Noon Chai to total sodium intake in Kashmir, its widespread and repeated daily consumption suggests that it may represent an important dietary source of sodium for certain population groups [35,61–65].

The increasing popularity of preventive healthcare and functional foods has created opportunities for promoting scientific understanding of Noon Chai. Rather than viewing the beverage exclusively through the lens of risk, future public health efforts are emphasizing its beneficial phytochemical composition while encouraging preparation methods that optimize health outcomes. Such an approach aligns with contemporary public health principles that seek to preserve cultural heritage while reducing disease risk.

Research Gaps and Future Directions

Despite centuries of consumption and considerable cultural significance, scientific investigations specifically focused on Kashmiri Salt Tea remain remarkably limited. Most current knowledge concerning the beverage's health effects is extrapolated from studies of green tea, tea catechins, or isolated phytochemicals. Although such evidence provides valuable insights, important questions regarding the chemistry, bioavailability and physiological effects of Noon Chai remain unanswered.

One of the most important research priorities involves comprehensive chemical characterization of traditionally prepared Noon Chai. Modern analytical techniques such as high-performance liquid chromatography (HPLC), liquid chromatography-mass spectrometry (LC-MS), gas chromatography-mass spectrometry (GC-MS) and nuclear magnetic resonance spectroscopy (NMR) could provide detailed information regarding phytochemical transformations occurring during alkaline brewing. Such studies would help identify the compounds responsible for the beverage's unique color, flavor and biological properties. Further investigation is also required to quantify changes in catechin concentrations during preparation. The alkaline environment generated by sodium bicarbonate is known to influence polyphenol stability, yet the extent to which these transformations affect biological activity remains poorly understood. Determining whether degradation products retain antioxidant and anti-inflammatory functions would significantly improve understanding of the beverage's nutritional value.

Another critical area of research concerns bioavailability. Interactions between tea polyphenols and milk proteins may influence gastrointestinal absorption, metabolism and physiological activity. Although previous studies examining milk-

tea interactions have produced conflicting results, little information exists regarding these effects under the specific conditions used for Noon Chai preparation.

Human clinical trials represent another major research need. To date, no large-scale intervention studies have evaluated the health effects of Noon Chai consumption directly. Future investigations should examine its influence on blood pressure, lipid profiles, inflammatory biomarkers, glucose metabolism, gut microbiota composition, cognitive performance and cardiovascular risk factors. Such studies would provide evidence-based guidance for dietary recommendations and public health policies.

Population-based epidemiological studies in Kashmir would also be valuable. Understanding consumption patterns, serving sizes, sodium concentrations and associations with disease outcomes could help clarify the beverage's long-term health implications. These investigations would be particularly important given the growing prevalence of hypertension and other non-communicable diseases in the region.

Future research should additionally explore opportunities for product optimization. Modifying preparation techniques to reduce sodium content while preserving traditional sensory characteristics may represent an effective strategy for enhancing the beverage's nutritional profile. Innovations in recipe formulation, ingredient selection and brewing practices could potentially improve health outcomes without compromising cultural acceptance.

Finally, interdisciplinary collaborations among food chemists, nutritionists, public health researchers, clinicians and social scientists will be essential for advancing understanding of Noon Chai. Such collaborations would facilitate a holistic evaluation of the beverage that integrates cultural, nutritional, biochemical and epidemiological perspectives.

CONCLUSION

Kashmiri Salt Tea, popularly known as Noon Chai, represents far more than a traditional beverage. It is a cultural symbol, a dietary staple and a unique example of how food chemistry, nutrition and tradition intersect within a single culinary practice. Its preparation through prolonged boiling of green tea leaves in the presence of sodium bicarbonate and salt creates a chemically distinct beverage characterized by its iconic pink color, complex flavor profile and unique phytochemical composition.

Current evidence indicates that Noon Chai contains a diverse array of bioactive compounds, including catechins, flavonoids, amino acids, alkaloids and minerals derived primarily from green tea. These compounds exhibit antioxidant, anti-inflammatory, cardioprotective, neuroprotective and metabolic activities that may contribute positively to human health. Emerging research further suggests that tea polyphenols influence gut microbiota composition, immune regulation and chronic disease prevention, highlighting the broader functional significance of tea-derived phytochemicals.

At the same time, the traditional use of salt and sodium bicarbonate raises legitimate concerns regarding sodium intake and cardiovascular health. Excessive sodium consumption remains a major contributor to hypertension and related non-communicable diseases worldwide. Consequently, the health effects of Noon Chai cannot be evaluated solely on the basis of its beneficial phytochemical content. Rather, they reflect a dynamic balance between its potential health-promoting properties and its contribution to overall dietary sodium exposure.

The evidence reviewed in this article suggests that Noon Chai should neither be regarded as a universally beneficial functional beverage nor dismissed as merely a source of dietary sodium. Instead, it should be recognized as a nutritionally complex traditional food whose health effects depend upon preparation practices, frequency of consumption, overall dietary patterns and individual physiological characteristics.

From a broader perspective, the study of Noon Chai illustrates the importance of scientifically investigating traditional foods and beverages. Such investigations not only contribute to understanding of human nutrition and health but also help preserve valuable elements of cultural heritage. As interest in functional foods and personalized nutrition continues to grow, traditional beverages such as Noon Chai may offer important insights into the relationship between culture, chemistry and health.

Future research combining food chemistry, nutritional science, clinical medicine and public health will be essential for establishing evidence-based recommendations regarding Noon Chai consumption. Such efforts will help ensure that this cherished component of Kashmiri culture continues to be enjoyed while promoting optimal health outcomes for future generations.

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FUTURE SCOPE

Future investigations should focus on standardized chemical profiling of Noon Chai, assessment of bioactive compound bioavailability, clinical evaluation of health outcomes, sodium-reduction strategies and the development of evidence-

based dietary recommendations. Such studies will contribute to preserving the cultural significance of Noon Chai while maximizing its nutritional and public health benefits.

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