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Review article

Functional Vinegar-Based Beverages and Their Effects on Health

Merve Özer [a], Duygu Benzer Gürel [a,*], Melisa Gürhan [a],
Ebru İşitmezoğlu [a] & Besime Bakiler [a]

[a] Department of R&D of Fersan Fermantasyon Ürünleri San. Tic. A.Ş., İzmir, Türkiye

Abstract

The production of functional foods has become one of the focal points of advancements in the food industry. The functional beverage market is expected to reach $208.13 billion by 2024, with a projected Compound Annual Growth Rate (CAGR) of 7.5% from 2022 to 2027. Consumers increasingly recognize the importance of the relationship between diet and health in maintaining overall well-being. Additionally, factors such as fast-paced lifestyles, high consumption of convenience foods, inadequate exercise, and the rising trend of self-medication are considered critical drivers for the growing popularity of functional foods. Research generally supports the idea that certain food components, when consumed as part of a healthy diet, have protective potential against the development of many age-related diseases. These observations have prompted increased research into identifying specific bioactive components in foods, such as antioxidants, that may be responsible for improving and maintaining human health. Vinegar, widely used around the world, can be produced using various methods and raw materials, including grains, wheat, and fruits. Vinegar has been reported to have various health-promoting effects, including immune modulation, suppression of cardiovascular diseases, prevention of appetite increase, and reductions in serum cholesterol levels, arterial stiffness, and blood pressure. With these effects, functional vinegar-based beverages are among the functional drinks of interest due to their potential health benefits, attributed to their rich bioactive components such as acetic acid, polyphenols, flavonoids, and organic acids. Consumption of vinegar-based beverages has been associated with positive effects on metabolic health, such as increasing insulin sensitivity and improving lipid profiles. Furthermore, the anti-inflammatory properties of vinegar can enhance immunity and lower infection risk. However, more research is required to assess the long-term effects and potential risks of regular vinegar consumption. Overall, functional vinegar-based beverages offer a valuable contribution to a healthy diet, with the potential to support metabolic health, enhance immunity, and combat oxidative stress. This review discusses the multifaceted health effects of these beverages, focusing particularly on their antioxidant properties, which play a crucial role in mitigating diseases associated with oxidative stress.

Keywords: Bioactive Compounds, Functional Beverages, Health, Vinegar.

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*** Corresponding author:**

Dr. Duygu Benzer Gürel is an R&D and Product Executive at Fersan Fermentation A.Ş., with extensive experience in food innovation, new product development, and scientific research. She holds a Ph.D. in Food Engineering from Manisa Celal Bayar University, an M.Sc. in Food Engineering from Namık Kemal University, and a B.Sc. in Food Engineering from Ege University. Her expertise includes functional foods, food microbiology, packaging solutions, and alternative protein sources. She has led academic and industrial research projects and collaborated on government-funded R&D initiatives. She has published in international journals on topics such as food preservation, alternative protein formulations, and innovative food processing technologies. Duygu has a strong background in market research, consumer trends, and sustainable food production.
Email: duygu.gurel@fersan.com.tr

INTRODUCTION

Recently, there have been significant changes in eating habits with the rising health awareness of consumers. These changes are especially evident in the beverage industry, where functional beverages are replacing traditional sugary and carbonated beverages. Functional beverages differ from traditional ones, especially due to their natural ingredients, and they stand out with their positive effects on health (Dini, 2019).

The World Health Organization's (WHO) recognition of the importance of functional foods and beverages has led to the awareness of such products by consumers. Thus, functional beverages have become a rapidly growing both in the market and in the food industry due to its health effects (Gupta et. al., 2023). Functional beverages contain bioactive ingredients that not only quench thirst but also provide health benefits (Misra et. al., 2021). In the food industry, functional foods are rapidly gaining popularity by offering various benefits, such as immune system support, digestive health improvement, and metabolism regulation. Functional beverages may contain health-promoting ingredients such as vitamins, minerals, probiotics, prebiotics, herbal extracts, proteins, and antioxidants (Gupta et. al., 2023). Consumption of these beverages provides various benefits such as supporting gut health, boosting the immune system, and preventing metabolic diseases (Praveen & Brogi, 2025).

Vinegar-based beverages are increasingly receiving attention among functional beverages. Historically, vinegar has played an important role in food preservation, medicinal applications, and traditional health practices. Scientific research supports these traditional uses by demonstrating the potential benefits of vinegar on metabolic diseases (Hosseini et. al., 2025). In particular, apple cider vinegar, grape vinegar, and various plant-based vinegars are rich in bioactive compounds and have antioxidant, anti-inflammatory, and metabolic-regulating effects (Xia et. al., 2020).

Excessive consumption of traditional sugary beverages is known to contribute to health problems such as obesity, type 2 diabetes, and cardiovascular diseases. On the other hand, vinegar-based beverages have become an alternative option due to their low sugar content and metabolism-supporting effects (Sugiyama et. al., 2010). Moreover, an analysis of consumer preferences indicates that the market share of functional beverages with natural ingredients and health benefits is growing rapidly (Fataliyev et. al., 2024).

This review article aims to examine the functional and health benefits of vinegar beverages based on scientific studies. The bioactive components of vinegar, its effects on metabolic diseases, and probiotic and antioxidant properties will be discussed from a consumer acceptance and public health perspective. This study aims to guide the development of new strategies for the food and beverage industry.

Functional Beverages and Their Importance Today

In recent years, healthy eating habits are becoming increasingly important, and consumers are turning to beverages that not only quench thirst but also offer health benefits. Functional beverages are products that contain bioactive ingredients that support body functions in addition to essential nutrients. These beverages offer various health benefits, such as boosting the immune system, improving digestive health, regulating metabolism, and reducing oxidative stress (Essa et. al., 2023).

There are many different types of functional beverages available today and they can be generally divided into eight main categories, including energy drinks, performance-enhancing drinks, weight management drinks, and digestive health, immune, cardiovascular, and cognitive health drinks (Gupta et. al., 2023). Beverages in this category are formulated with probiotics, vitamins and minerals, herbal extracts and antioxidants (Nazir et al., 2019). The popularity of these beverages is rising with the awareness of consumers and the spread of healthy living trends. In addition, the fact that the disease-preventive and health-protective effects of functional beverages are supported by scientific studies makes these products a wide place in the food and beverage industry (Praveen & Brogi, 2025).

In recent years, research suggests that research has indicated that regular consumption of functional beverages can help prevent cardiovascular disease, regulate blood glucose levels, and support weight loss. However, functional beverages that contain natural ingredients and no additives are becoming increasingly popular among consumers (Hosseini et. al., 2025).

Functional beverages play an important role not only in individual health but also in public health. Beverages containing prebiotics and probiotics can support the digestive system and strengthen the immune system by balancing the gut microbiota (Sugiyama et. al., 2010). In addition, the antioxidant properties of functional beverages may protect cellular health by reducing free radical-induced oxidative stress (Kim et. al., 2012).

The food and beverage industry is making major investments in the development of functional beverages. Global market analysis shows that functional beverages will grow substantially in the coming years (Mintel, 2025). Therefore, vinegar beverages, which are among the functional beverages, are gaining increasing attention due to their bioactive ingredients and health benefits. Vinegar is traditionally known to have health-promoting properties and scientific research confirms these effects (Fataliyev et. al., 2024).

As functional beverages become increasingly popular, the health effects of their bioactive components, unlike those of traditional beverages, are receiving increased scientific attention. In addition, vinegar-based beverages are distinguished by their antioxidant, antimicrobial, and metabolic regulatory properties and are preferred by health-conscious consumers (Xia et. al., 2020).

Functional Properties and Effects of Vinegar Drinks on Health

The increasing trend towards healthy eating in our country has led to the introduction of high-vitamin and functional products into the sector, indicating a promising future for industry. Diseases such as obesity, hypertension, and diabetes are associated with food, leading to differences in the foods consumed by consumers. Besides their high caloric content, carbonated beverages have been criticized in the literature for having little or no nutritional value and for being the largest contributor to refined sugar in the diets of young people (Rampersaud et. al., 2003). Vinegar is a food product produced through fermentation, containing about 4-5% acetic acid and providing characteristic taste and aroma. It contains various fruit acids, color compounds, salts and fermentation products. Vinegar is produced by processing a suitable agricultural raw material first with alcohol and then with acetic acid fermentation, making it suitable for human consumption. With these characteristics, vinegar is important both as a common ingredient for culinary uses and as a functional product for health (Abe et. al., 2007; Öztürk, 2022). It has a strong flavor and aroma due to acetic acid fermentation (Budak et. al., 2011). Therefore, the most important organic acid in vinegars is acetic acid, which also acts as a buffer in acidic foods (García Romero et. al., 1993). Depending on the bioactive substances in its composition, vinegar has been reported to have antitumor, antimicrobial and anti-infective effects (Johnston & Gaas 2006). In studies investigate that the effects of vinegar on human health. The main functional components of vinegar are explained below.

Acetic acid: It is the main component of vinegar and is known for its metabolism-accelerating effect. Acetic acid regulates glucose metabolism by increasing insulin sensitivity and helps stabilize blood sugar levels (Sugiyama et. al., 2010). It can also support weight management due to its appetite-suppressing effect (Kim et. al., 2012).

Polyphenols: Vinegar contains significant amounts of polyphenols since it is derived from grapes, apples and other fruits and other plant-based sources. Polyphenols are known to be powerful antioxidant components that prevent cell damage by neutralizing free radicals. They are also known for their anti-inflammatory effects (Xia et. al., 2020).

Organic Acids: Organic acids, such as citric, malic, lactic, and tartaric acids, support digestion and improve gut health. These acids also regulate stomach acidity, allowing the digestive system to function more efficiently (Gupta et. al., 2023).

Melanoidins are produced during vinegar fermentation and are known for their antioxidant and antimicrobial properties. They have the potential to protect food and support the immune system (Hosseini et. al., 2025).

These bioactive components are the main elements that provide the positive effects of vinegar drinks on health, and their regular consumption has many benefits that support the metabolic and

immune systems. Vinegar contains bioactive components that have been shown to support energy expenditure and appetite control by increasing the metabolic rate. Research suggests that vinegar regulates glucose metabolism by increasing insulin sensitivity and therefore may help prevent type 2 diabetes (Sugiyama et al., 2010). In addition, bioactive compounds including phenolic compounds and acetic acid may protect cells from free radical damage by reducing oxidative stress (Kim et. al., 2012).

The general properties of functional beverages include antioxidant, antimicrobial, probiotic supportive, and metabolic regulatory effects. Vinegar improves digestive health by supporting the intestinal microbiota through its organic acids, phenolic compounds, and enzymes it contains and exhibits an anti-inflammatory effect in the body (Gupta et. al., 2023). In particular, fermented products such as apple cider vinegar may provide enhanced health benefits when enriched with probiotic bacteria that contribute positively to intestinal health (Praveen & Brogi, 2025).

Incorporating vinegar, known for its health benefits, into beverage production creates a high-value functional product that serves as a year-round alternative to existing market beverages. Meanwhile, its sugar content is reduced using various natural and artificial sweeteners in formulations. In a study on a functional beverage developed using spice combinations and apple cider vinegar, sensory evaluation of beverages enriched with spices such as ginger, cloves, cinnamon, black pepper, turmeric, and cardamom was carried out. It was determined that all samples were positively evaluated by consumers according to color, appearance, smell, taste and general acceptability criteria. The study demonstrates that the combination of vinegar with different spice extracts and flavorings offers new opportunities for the production of an alternative cold drink. When the extracts obtained before and after gastrointestinal digestion were analyzed, the highest total antioxidant capacity among all methods was observed in the beverage formulation with stevia addition and six different spices (Terakye et. al., 2019).

Research on vinegar-based functional beverage development has focused on the production of vinegar from soursop (*Annona muricata L.*) fruit. In this study, soursop vinegar was produced using alcoholic and acetic fermentation processes, and its physicochemical, toxicity, and sensory properties were investigated. The resulting vinegar was characterized by high acetic acid content (3.5 ± 0.3%), total phenolic compounds (220 ± 20 ppm gallic acid equivalent) and FRAP (ferric reducing antioxidant power) value (222 ± 2 μM ascorbic acid equivalent). Toxicity assays indicated that soursop vinegar increased cell viability in human liver cells (HepG2) at low concentrations and was non-toxic in the fish embryo toxicity test (FET). Sensory analysis revealed that soursop vinegar was perceived as less sour and sweeter than commercial vinegar. This research demonstrates that the conversion of soursop fruit into vinegar offers a potential method to reduce fruit waste and may contribute to the development of healthy alternative beverages (Ho et. al., 2021). Additional research in functional beverages focuses on the production of date-based fermented beverages and vinegar. Date fruit is a raw material rich in sugars, dietary fibers, minerals, vitamins, and phenolic compounds, which make it highly suitable for the

development of functional beverages. Date juice can be transformed into various fermented products such as wine and vinegar through fermentation. Following the production of wine by alcoholic fermentation, date vinegar has been obtained using acetic fermentation. Furthermore, date juice and syrup have been used in the production of wine. Moreover, date juice and syrup can be transformed into fermented beverages by lactic acid fermentation (Cantadori et. al., 2022).

Research on functional beverages indicates that different raw materials can be fermented into health-promoting products. In a study conducted in this context, the production of a herbal beverage containing longan, red jujube, and banana vinegar was optimized and its anti-fatigue activity was investigated. In the study, the effect of longan extract, red jujube extract, brown sugar solution, and banana vinegar ratios on sensory quality was evaluated and the optimal formulation was determined. In addition, the anti-fatigue activity of the drink was evaluated in mice based on swimming time, blood lactate level, and urea nitrogen concentration. As a result of the study, it was determined that this drink increased swimming time, reduced blood lactate level, and urea nitrogen concentration in mice. This study is an important example for the development of functional beverages with vinegar and demonstrates that the combination of herbal ingredients and vinegar can produce innovative beverages that are both sensory acceptable and provide anti-fatigue effects (Lu et. al, 2023). White wine vinegar, besides being widely used in the kitchen, has health benefits such as blood sugar regulation, appetite control, weight management, cholesterol-lowering properties and antimicrobial properties attributable to its acetic acid content. The developed beverage was formulated with the following ingredient ratios: 20% fruit or fruit extract, 20% sugar, 10% natural white wine vinegar (6% acidity), 1% aromatic herbs, and 0.2% spices. As a result, a functional beverage with retained organoleptic properties, high nutritional value, and no artificial additives were obtained. This study makes an important contribution both to expanding the range of functional beverages and utilizing local agricultural resources (Andronic et. al., 2022).

Thus, the functional properties of vinegar beverages have great potential not only for individual health but also for providing natural and healthy alternatives in the food industry. Therefore, more research is required to scientifically evaluate vinegar-based beverages and increase consumer acceptance.

Regulation of Blood Glucose and Metabolic Health

Vinegar is known for regulating blood glucose levels and its positive effects on metabolic health. In particular, thanks to its acetic acid content, it can reduce postprandial blood glucose fluctuations by increasing insulin sensitivity (Siddiqui et. al., 2018; Cheng et. al., 2019). Several studies demonstrate that vinegar consumption reduces the levels of after-meal blood glucose and may help predict type 2 diabetes (Sugiyama et al., 2010; Yang et. al., 2010).

In the study by Kausar et al. (2019), a significant change was found in total cholesterol (P = 0.002), triglyceride (P = 0.002), and hip-to-waist ratio (P = 0.002) values (on average) in patients with type 2 diabetes compared to the placebo group. The study reported that apple cider vinegar consumption may be effective in reducing hypercholesterolemia and hypertriglyceridemia in patients with type 2 diabetes.

The increase in blood sugar after eating is known as after-meal hyperglycemia. Prevention of this condition has an important role in the prevention or treatment of chronic diseases. In some reports published in the last twenty years based on clinical studies, it has been reported that consuming vinegar with meals lowers postprandial glucose levels (Shishehbor et al., 2017).

The effect of vinegar on glucose metabolism is associated with slowing carbohydrate digestion and prolonging gastric emptying time. This helps prevent hyperglycemia by regulating postprandial blood sugar levels after meals (Kim et al., 2012). The positive effects of vinegar on insulin resistance have also been observed. Acetic acid can improve insulin sensitivity by increasing glucose uptake in muscle tissues (Khalifa et. al., 2024; Xia et al., 2020).

High blood glucose levels and insulin resistance associated with metabolic syndrome may increase the risk of cardiovascular diseases and obesity. In this perspective, regular consumption of vinegar drinks is recommended as a strategy to support metabolic health. Moreover, vinegar drinks can be consumed as part of a healthy diet, as they are low in calories and contain natural ingredients (Gupta et al., 2023).

The positive effects of vinegar on metabolic diseases are supported by the regulatory effects of its bioactive components on cellular mechanisms (Siddiqui et al., 2018). Therefore, regular consumption of vinegar beverages may have positive effects on metabolic health in the long term by enhancing blood glucose regulation.

Lipid Metabolism and Obesity Management

Vinegar has important regulatory effects on lipid metabolism and may help with weight management. Studies indicate that vinegar may provide positive effects on body composition by reducing fat storage (Behesti et. al., 2012). Acetic acid accelerates energy metabolism by increasing fatty acid oxidation and prevents lipogenesis (Kim et al., 2012).

In terms of obesity control, appetite suppressing properties of vinegar are also prominent. Acetic acid has been shown to increase the feeling of satiety by prolonging gastric emptying time, thereby reducing calorie intake (Xia et al., 2020). In addition, the fat-burning effects of vinegar have also been observed. Some studies have shown that vinegar consumption helps to reduce waist circumference and body fat (Sugiyama et al., 2010; Petsiou et al., 2014; Samad et al., 2016; Beh et. al., 2017; Gökırmaklı et. al., 2019).

In addition, vinegar is believed to support cardiovascular health by lowering cholesterol and triglyceride levels. It has been reported that regular vinegar consumption can lower low-density lipoprotein (LDL) levels and increase high-density lipoprotein (HDL) levels (Petsiou et al., 2014; Halima et. al., 2017; Hosseini et al., 2025). Regular consumption of vinegar beverages may be an effective tool in the fight against obesity by regulating lipid metabolism. It is regarded as a nutritional approach to supporting healthy weight management due to its natural composition and low-calorie profile.

A randomized clinical trial was conducted by Khezri et. al. (2018) to evaluate the regulatory effects of apple cider vinegar on body weight and serum metabolic profiles in overweight or obese individuals. In the study, a significant decrease in body weight, body mass index, hip circumference, visceral adipose index, and appetite scores were observed in the group administered apple cider vinegar. In another study, the anti-obesity and anti-inflammatory effects of synthetic acetic acid vinegar and Nipa vinegar were compared in mice fed a high-fat diet (Beh et al., 2017). As a result of the results obtained from the study, findings indicate that high-dose Nipa vinegar administration can potentially support the reduction of obesity by altering lipid metabolism, inflammation, and gut microbiota composition in high-fat diet-induced obese mice.

After a 9-week experiment conducted by Chou et al. (2015), it was observed that hamsters fed a high-fat/cholesterol diet had greater ($P < 0.05$) weight gain, greater relative visceral fat sizes, serum and liver lipid levels and serum cardiac indices than those fed a low-fat/cholesterol diet. In conclusion, rice vinegar supplementation contributed to lipid-lowering and antioxidant effects on hamsters fed a high-fat diet.

The Effects on Cardiovascular Health

Vinegar beverages can have multiple benefits on cardiovascular health. Vinegar, which is particularly rich in acetic acid and polyphenols, may reduce the risk of heart disease by regulating blood pressure and supporting vascular health (Sugiyama et al., 2010). Studies have indicated that vinegar consumption helps control hypertension and reduces arterial stiffness (Hosseini et al., 2025).

The antioxidants contained in vinegar may lower the risk of atherosclerosis by inhibiting LDL oxidation. Regular consumption of vinegar is remarkable for its effects in heart rhythm stabilization and supporting the circulatory system (Xia et al., 2020).

In a study by Ali et. al. (2018), a new beverage was developed using date vinegar and garlic juice. Two glasses (500 mL) of the newly developed beverage or placebo were consumed daily for 7 weeks. The dose of the new beverage (500 mL) was found to lower total cholesterol (from 260.10±17.9 to 198.90±17.31 mg/dL) and C-reactive protein (from 8.04±1.34 to 4.45±1.42 mg/L), as well as heart rate (60-125 beats/min lower than the control group) and mean blood pressure (80-120 mm Hg lower than

the control group). These results suggest that this vinegar-based beverage improves the concentration of lipids and inflammatory biomarkers and may be useful for people concerned about hypertension.

In addition, some studies have demonstrated that vinegar has anti-inflammatory effects, reducing inflammation in the veins and thus improving blood flow (Kim et al., 2012). It is suggested that vinegar drinks can be considered as a nutritional strategy to prevent cardiovascular diseases due to these properties.

Although more clinical studies are needed, current scientific data confirm the cardiovascular health-supporting effects of vinegar drinks. Therefore, it is thought that regular vinegar drink consumption can be recommended as part of a healthy lifestyle.

The Effects on Intestinal Health

Vinegar drinks have important benefits on gut health. Fermented vinegars can maintain the balance of the digestive system by supporting the gut microbiota. Prebiotics promote the growth of beneficial bacteria and suppress harmful microorganisms (Hosseini et al., 2025).

The organic acids contained in vinegar facilitate digestion by balancing stomach acidity and can help prevent digestive problems such as constipation by regulating gut movements (Gupta et al., 2023). However, vinegar can improve gut health in the long term by supporting the nutrition of beneficial bacteria in the gut due to its prebiotic properties (Praveen & Brogi, 2025).

Studies have reported that consumption of vinegar beverages strengthens intestinal barrier functions and reduces intestinal inflammation (Xia et al., 2020). In addition, melanoidins and polyphenols found in fermented vinegars help protect cells in the intestinal wall by supporting intestinal health (Sugiyama et al., 2010).

Vinegar is used worldwide both as a fermented condiment and as a functional food. In a study, the effects of Shanxi aged vinegar (SAV) on gut microbiota and metabolome were examined in normal mice. Consumption of SAV decreased inflammatory factors and increased the expression of immunoglobulins, NK cells and CD20, components of the immune system. Furthermore, SAV altered the gut microbiota, increasing *Verrucomicrobia, Akkermansia*, *Hungatella* and *Alistipes* species, while decreasing bacteria such as *Firmicutes* and *Lachnospiraceae*. Metabolic changes in the gut affected the levels of amino acids, carbohydrates and bile acids and modulated immune regulatory mechanisms (Xia et. al., 2024). These findings suggest that vinegar consumption may have positive effects on health by regulating gut microbiota and metabolome balance.

In a study examined the preventive effects of vinegar and acetic acid, the active component of vinegar, on ulcerative colitis in mice. Vinegar (5% v/v) or acetic acid (0.3% v/v) treatment significantly reduced the disease activity index and associated histopathological scores, such as attenuated body

weight loss. Vinegar was also found to have the function of regulating the gut microbiota of mice (Shen et. al., 2016).

In conclusion, regular consumption of vinegar drinks can support digestive system functions by improving gut health. Due to these properties, it positively affects the gut microbiota, enhances immune funtion and contributes to overall health.

Vinegar Drinks from a Public Health Perspective

Vinegar drinks can play an important role in terms of individual health benefits and public health. Modern lifestyles and dietary habits, especially the increased consumption of sugary drinks, have led to the increased prevalence of obesity, diabetes, and cardiovascular diseases (Hosseini et al., 2025). In addition, vinegar drinks may contribute to public health by offering a healthy alternative with their natural ingredients and low sugar content.

The regulatory effects of vinegar on metabolism are among the factors that can directly affect public health. For instance, preferring low-glycemic index beverages can help prevent diseases such as diabetes and insulin resistance (Gupta et al., 2023; Gökırmaklı et. al., 2019). Furthermore, supporting gut health, vinegar drinks are known to have immune-boosting effects due to their bioactive properties (Xia et al., 2020).

When evaluated in terms of social nutrition habits, various policies are being developed for the integration of functional beverages into public health. For example, the public health programs organized to reduce the consumption of sugary beverages, vinegar beverages can be encouraged to be offered as an alternative (Sugiyama et al., 2010). The health benefits of vinegar-based beverages can be emphasized by conducting awareness studies among consumers.

In addition, research across different age group suggest that vinegar beverages may be particularly beneficial for older individuals and people with digestive sensitivities (Praveen & Brogi, 2025). At the same time, reducing consumption of sugary drinks in childhood and promoting healthy alternatives could be an important step in long-term public health strategies.

Overall, the beneficial effects of vinegar beverages on public health are supported by scientific data. Additionally, encouragement of healthy eating habits and the inclusion of functional beverages in the daily diet are of great importance in terms of protecting and improving public health.

CONCLUSION

The beneficial effects of vinegar beverages on health are supported by scientific studies. These beverages have an important place among functional foods due to their benefits in blood sugar regulation, lipid metabolism management, cardiovascular health, and gut microbiota. Their regular consumption can help prevent metabolic diseases and support the immune system.

In the future, more clinical studies are needed to understand and optimize the functional properties of vinegar beverages. In particular, extensive research is needed to determine the effects of vinegar beverages on different age groups and individuals with various health conditions. In addition, it is important to improve taste profiles and enrich them with different flavor combinations to increase consumer taste.

The functional beverage market is growing rapidly, and vinegar drinks are expected to secure a strong position in this market. From a public health perspective, it is important to promote these beverages as part of healthy eating strategies due to their low sugar content and natural ingredients. In the future, it would be beneficial to develop public information campaigns and regulatory policies to promote vinegar drinks and increase consumption rates as part of health policies.

In conclusion, vinegar drinks have great potential for functional nutrition and public health. However, more scientific studies are needed to determine the long-term effects of these beverages on health. In addition, product development processes should be carried out to ensure that these beverages are made available to a wider consumer.

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