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REVIEW

Kombucha as a Health-Beneficial Drink for Human Health

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Abstract
Kombucha is a unique fermented beverage made from a symbiotic culture of yeast and bacteria. Kombucha is normally based on black tea added to water, then sugar is added as a substrate for fermentation in this beverage. This unique beverage is composed of amino acids, flavonoids, vitamins, and some active enzymes. Several beneficial health effects such as antioxidant, antimicrobial effects have been reported as a result of probiotics and prebiotics presence. These health effects of kombucha are attributed to its bioactive chemical and biological agents of probiotics bacteria *e.g.*, *Gluconobacter*, *Acetobacter* and yeasts like *Saccharomyces* sps., along with glucuronic acid as the main sources of the health protection. This review focuses on the beneficial effects of Kombucha including antimicrobial, antioxidant, anti-cancer antidiabetic properties, as well as liver protection, treat of gastrointestinal problems, AIDS, gastric ulcers, obesity (and energy production), detoxification, and skin health.

Keywords Therapeutic effect · Kombucha · Antioxidant · Antimicrobial · Chemical components

Introduction

Kombucha is an Asian fermented drink which is popular all around the world over the last decade due to having various therapeutic effects like antimicrobial, antioxidant, anticarcinogenic, antidiabetic, liver detoxification, treatment of gout, AIDS, digestion disorders, gastric ulcers and obesity. It has also shown an impact on the general heath, immune response and skin improvement [1]. All the above health effects have made a desirable interest for consuming this product [2]. Kombucha is traditionally made from black tea and also other kinds of tea like green, oolang, etc. with addition of sugar [3].

Kombucha is slightly sweet, sour acidic (pH around 3-3.5) and carbonated, which makes it more acceptance in consumers [4]. Kombucha is normally based on black tea. For its preparation, tea (5 g) is added to water (1 L), then sugar is added as a substrate for fermentation in this beverage [5]. A Symbiotic Culture of Bacteria and Yeast (SCOBY) is used as the starter culture for fermentation [6]. SCOBY create a powerful symbiosis media to inhibit the contaminating microorganism's activity [7]. In aerobic condition, SCOBY is able to make kombucha by fermenting tea and sugar during 7–10 days in. It is composed of organic acids, amino acids, flavonoids, vitamins, and some active enzymes [8].

It is reported that the demand and usage for kombucha has enhanced in many countries during COVID pandemic due to the reported beneficial health effects [9–11]. So, this review focus on several articles on kombucha published in PubMed, Scopus and Web of Science (WoS).

Chemical Components of Kombucha

The main chemical components of kombucha are shown in Fig. 1.

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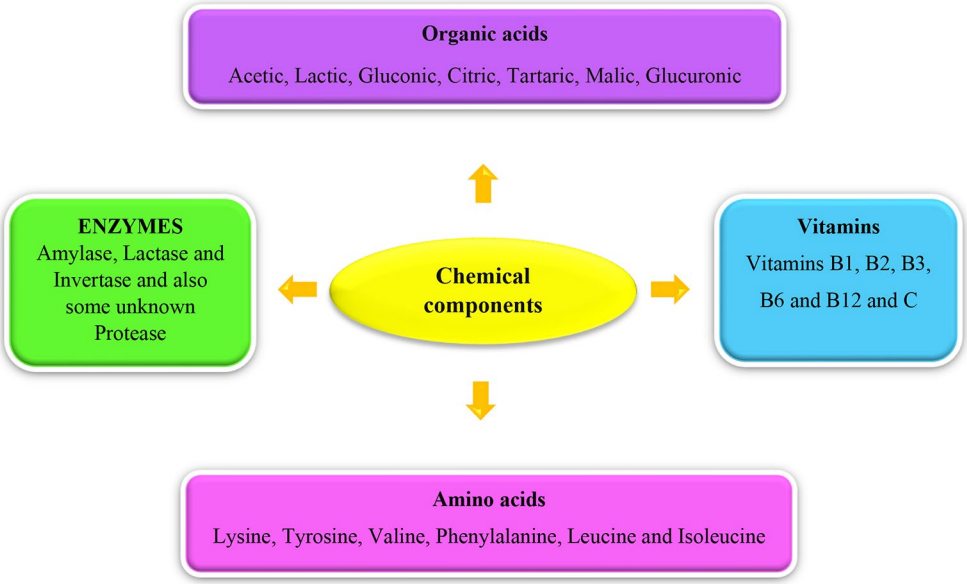

Fig. 1 The chemical components in kombucha

Simple Organic Acids

The acetic, lactic and gluconic acids are the main organic acids in Kombucha with antimicrobial activity. The citric, tartaric, malic, glucuronic and oxalic acids are less concentrated in Kombucha fermented tea [12]. In general, simple organic acids have beneficial effects on the digestive process [13]. Glucuronic acid is able to bind to toxic products produced by the liver by consuming the drugs (aspirin and morphine), toxins and other harmful substances. These compounds are first hydroxylated in the liver by the cytochrome enzyme and their solubility in the aqueous phase increases. Liver binds these compounds to glucuronic acid to increase solubility and then excreted by glucaric acid [12]. Lactic acid helps in balancing of bases and acids in the body and ultimately helps blood circulation [7]. In addition, acetic acid is a potent bactericidal compound that prevent the growth of many food-contaminating microbes [12]. Gluconic acid is a bactericide that frequently used in the food industry as a food preservative [14].

Vitamins

A good diet should include enough carbohydrates, fats, proteins and vitamins. Small amounts of vitamins must be present in the diet, otherwise majority of natural biochemical reactions in the body will be severely hampered [15]. Vitamins B_1, B_2, B_3, B_6 and B_{12} and ascorbic acid have been reported in fermented kombucha tea. In addition, for producing vitamins especially vitamin B_{12}, which is not present in most people's diets [16]. Since the yeast biomass is known as a rich natural source of protein, B vitamins, and several trace minerals, it can produce vitamin B_{12} [5]. After vitamin C analysis in kombucha at different fermentation times (1–2 weeks) from *Annona muricata* L. leaves, it is revealed that vitamin C amount enhanced noticeably during fermentation which possess antioxidant influence towards free radicals [11, 12].

Amino Acids

Kombucha is rich in essential and non-essential amino acids. Fermented kombucha tea has been reported to contain free amino acids such as lysine, tyrosine, valine, phenylalanine, leucine and isoleucine [17]. Among the amino acids, lysine has the highest content and methionine has the lowest amount in kombucha. As fermentation time progresses, the levels of amino acids such as isoleucine and leucine increase. Among the non-essential amino acids, glutamic, alanine, aspartic acid and proline are more abundant amino acids in this category [15]. Kombucha also contains a compound called choline, which is involved in building phospholipids. Free amino acids, are claims to involve in health promoting processes [18].

Enzymes

Sugars, proteins and fats should be broken down into their building blocks by certain enzymes for absorption. The sugars and fats are broken down by amylase and lipase in the mouth and stomach respectively. Then they travel through the small intestine to the bloodstream, where they are transported to tissues and cells [19]. Kombucha tea contains amylase, lactase and also some unknown protease enzymes. Amylase breaks down starch into their building blocks. Lactase also breaks the bond between lactose disaccharide

and breaks it down into monosaccharide units; glucose and galactose. Kombucha enzymes have role in higher digestion efficiency [20]. *Saccharomyces* genera in kombucha, produces invertase (or *β*-fructofuranosidase) which breaks sucrose, into glucose and fructose through hydrolysis [21].

Therapeutic Effects of Kombucha

Many therapeutic effects are attributed to this unique fermented beverage. Antioxidant and antimicrobial effects, lowering cholesterol levels, reducing the risk of heart disease and diabetes, liver detoxification, lowering blood pressure, balancing the intestinal microbiota relieving arthritis, improving the immune system, prevention of cancer progression, stress reduction is some of them [22–26]. In this article, some of the most important ones are mentioned.

Antioxidant Activity of Kombucha

In general, the antioxidant activity of this beverage relates to some components like polyphenols, organic acids (glucuronic and lactic), amino acids, vitamins and a range of nutrients made after fermentation [24]. The polyphenol content of kombucha is enhanced during fermentation [15]. The kombucha antioxidant activity is more than unfermented tea due to the structural changes of the polyphenols and having low molecular weight components that are produced by yeasts and bacteria during fermentation [13]. The phenolic compounds would break down into simple molecules in acidic situations caused by SCOBY and the total phenolic content increases during fermentation [27]. Although more antioxidants will be produced in kombucha by enhancing the fermentation time, longer fermentation was found to further enhance acid accumulation, showing higher acidity and lower pH, while the bioactive components was reduced [28]. Some studies showed that the amount of vitamins C and E, beta-carotene are high in kombucha. Also having polyphenols along with some antioxidants, makes it stronger than black or green tea due to the fermentation process. Therefore, drinking this amazing drink helps to treat chronic diseases caused by oxidative stress [22, 29].

Antimicrobial Activity of Kumbocha

Kombucha has been reported to have antimicrobial activity against many pathogenic microorganisms [30]. This valuable drink can prevent pathogens activity such as *Helicobacter pylori* (causing stomach ulcers), *E. coli*, *Enterobacter cloacae, Staphylococcus* spp., *Agrobacterium tumefaciens*, *Bacillus cereus*, *Salmonella* spp., *Shigella*, *Leuconostoc*, etc. [31].

The low pH value of kombucha due to the presence of organic acids as well as proteins produced during fermentation, is the main responsible for the antimicrobial activity of this drink [30]. The antimicrobial effect of kombucha is reported to be due to the metabolites produced during the SCOBY metabolism [32]. Some research indicates that Kombucha not only has antibacterial properties but also antifungal activity due to the acetic acid production during fermentation [33]. The antimicrobial activity of Kombucha made from green tea has been proven to be much higher than other black tea [34]. The antimicrobial effect was only observed in fermented Kombucha with green or black tea [35]. The acidic state of fermented tea induces the antimicrobial effect and after the denaturation of fermented tea, the antimicrobial effects of kombucha appear [36]. The antimicrobial effect is due to the presence of organic acids (lactic, acetic, glucuronic acid) as well as other biologically active components like enzymes and proteins [37].

Kombucha as a Unique Probiotic Beverage

Probiotics are health-promoting microorganisms. A mixture of *Lactobacillus* and *Bifidobacterium* as well as a few yeast species such as *Saccharomyces cerevisiae* and *Saccharomyces boulardii* could be used for better functionality [38]. Probiotics can balance the body's vital microflora, improve the immune system and digestion, prevent the overgrowth of harmful bacteria, restore mental health, and decrease anxiety and depression levels [39]. Since the SCOBY are among beneficial microorganisms and have high resistance in acidic conditions, they can replace harmful microorganisms in the gastrointestinal tract, so kombucha can be considered as a unique probiotic food and these effects cause a huge interest in consuming kombucha [40].

Many studies have shown that kombucha is a community of probiotics and prebiotics. Prebiotics are indigestible compounds that are selectively metabolized by intestinal health-promoting bacteria and stimulate their growth and activity [41]. The micro cellulose of kombucha can help the growth of SCOBY in the gut [38]. The probiotic strains, thus selectively stimulating the growth and/or activity of the microbiota resident in the human gut. These preliminary results showed that kombucha stimulates these beneficial microorganisms, acting in a prebiotic manner. Phenolic compounds are among the possible prebiotic components in kombucha are. Some studies describe these phytochemicals as substances that exert prebiotic-like effects, being bioactive most associated with the promotion of healthy microbiome [38, 41].

The mechanisms that prebiotics represent the health benefits are as follows:

1. Stimulating the activity and growth of health-related intestinal bacteria [42].
2. Short-chain fatty acids production, especially butyrate with antimicrobial activity by reduction of intestinal pH [43].
3. Most popular prebiotics are inulin, fructans, lactulose, fructooligosaccharide, and galactooligosaccharide. The large intestine is a suitable for the prebiotic's activity [44].

Anti-Cancer Properties of Kombucha

Cancer is generally inherited and caused by some external factors such as chemical (toxins and some drugs), physical (gamma, X, alpha, beta, and ultraviolet rays) and biological (some viruses and bacteria). Cancer cells multiply unrestrained and out of control. Cancer comes in many forms and threatens people of almost all ages [23, 30].

Up to now, about 60,000 different synthetic materials have been developed around the world, and most of these compounds are produced massively before being tested for carcinogenesis.

Despite the relentless efforts, no definitive cure for cancer has yet been proposed over the past few decades. Surgery, radiation, chemotherapy, immunotherapy, and hormonal methods are the commonly used methods to treat cancer [30].

Using plant products with biologically active compounds have been getting atention thesedays.

Scientific research has shown the anti-cancer effects of kombucha. The Central Cancer Research Department in Russia proved that its daily consumption is associated with a very high persistence of cancer [45]. After World War II, kombucha-drinking regions in Russia represented fewer incidents of cancer diagnoses than the other regions exposed to pollution and toxins in the war [46]. It is reported that the anti-cancer ability of this drink relates to the polyphenols and other metabolites produced after fermentation [24]. The ability of tea polyphenols to inhibit mutation and cancer cell proliferation, induce apoptosis of cancer cells, and the ability to terminate metastases are known as anticancer properties [47]. Also, many kombucha's compounds like lactic, glucuronic, and gluconic acids, polyphenols, and vitamin C can reduce risk of cancer [48].

Kombucha contains disaccharide acids 1 and 4 lactones, which prevent the activity of glucuronidase (an enzyme that is directly related to cancer). Glucuronidase can hydrolyze glucuronide and produce some carcinogenic agents [33]. Kombucha is not a cure for cancer but due to having some beneficial compounds, this fermented beverage can help in preventing and controlling cancer [49].

Detoxification Properties of Kombucha Drink

Detoxification is a complex process for removing toxins from an organism. Europeans have drunk kombucha as a detoxifying agent on the digestive and blood systems [50]. This valuable process is performed by the liver in our bodies. Detoxification maintains liver health and also prevents cancers. The acids, enzymes, and other useful metabolites that are produced by microorganism's activity during the Kombucha fermentation can detoxify [30]. Most of these acids and enzymes are very similar to the natural chemicals produced by our body for detoxification. Therefore, the inclusion of kombucha tea in a person's diet reduces the pressure on the liver for detoxification [49].

Detoxification is mainly due to the ability of glucuronic acid to bind to toxic agents and increase their secretion out of the body through the kidneys and intestines [49]. Glucuronic acid is often a potent detoxifier and can bind toxins in the liver [51]. In addition to detoxification, drinking kombucha eliminates heavy metals and environmental pollutants via release through the kidneys. It is also useful for transmission of dangerous substances like bilirubin and extra steroid hormones from the body [52].

Potential of Liver Protection in Kombucha

Hepatotoxicity is the ability of the liver to protect itself from being damaged by toxins [53]. Many environmental contaminants cause liver toxicity. Many studies have been performed to evaluate the ability of this drink to make physiological changes as caused by many hepatotoxic agents like aflatoxin B_1, cadmium chloride, and acetaminophen [54–56]. Carbon tetrachloride (CCl_4) is a xenobiotic that induces peroxidation and free radical formation which ultimately causes liver damage [57]. Kombucha consumption inhibits the CCl_4 activity of and prevents liver damage in rats [58]. Also, it has been reported that kombucha increases the regeneration potentiality of the liver. During hepatotoxicity, triglyceride, aspartate transaminase, and alanine aminotransferase levels increased, and their levels were lower in mice fed with kombucha compared to the non-fed mice [59]. Investigating this drink's protective effects against thioacetamide as an inducer of hepatotoxicity showed that the polyphenols are responsible for antioxidant properties [56]. This study showed that kombucha prevents liver damage and contamination with environmental toxins [57].

Rle of Kombucha in Diabetes

Diabetes, which is usually inherited, occurs when the pancreas is unable to produce enough insulin. Insulin is a hormone that facilitates the entrance of blood sugar into the

cell. If the pancreas is damaged or insulin is not produced and secreted, the blood sugar rises [48]. The antidiabetic impact of kombucha was observed in Wistar albino rats after consumption of 14-day-fermentation kombucha [60]. Weight loss, excessive thirst, vascular injuries, and sometimes blindness are some of the diabetes problems [48]. For people with diabetes, low-sugar foods are usually recommended. Kombucha is very low in sugar (4 to 5%). Therefore, for diabetics, it is desirable to consume kombucha and other fermented foods in which the sugar content has been converted to other compounds. Kombucha is not a cure for diabetes, but it may help the body to produce more insulin and this reduces the need for insulin injections or pills. The findings represent that kombucha tea is a useful inhibitor of α-amylase activity in the plasma and pancreas and a good suppressor of increased blood glucose levels [60]. Therefore, consuming kombucha lowers blood sugar in people with diabetes [10, 23].

Impact of Kombucha on the Digestive System

The pH of stomach is in the range of 1 to 1.5 due to having hydrochloric acid. This acidic media is effective in killing germs, sterilizing food, and helping protein digestion. Stomach acid destroys protein structures and prepares them for enzymatic hydrolysis [48]. Peptic ulcer is one of the most common gastrointestinal disorders. It is claimed that dyspepsia leads to peptic ulcers and stress intensifies them [49]. Kombucha increases digestion efficiency and helps the stomach to get back to its healthy state. After regular consumption (250 ml a day for 2 months), consumers have reported an improvement in their digestion system [61]. It has also been claimed to activate intestinal and gastrointestinal functions and prevent some intestinal complications [62]. Butyric acid produced by yeasts in kombucha tea, helps in protecting cell membranes. Butyric acid in combination with gluconic acid would strengthen the stomach wall in conditions such as candidiasis [15]. Lactic acid produced during kombucha fermentation, can speed up blood circulation and prevent constipation [23].

Kombucha in Gout Treatment

Gout is the result of an increase in the amount of uric acid in the body. In this disorder, uric acid precipitates in the form of sodium urate crystals in joints and makes them swollen and painful. In addition, insoluble sodium urate crystals deposit in the kidneys and urinary tract, leading to the formation of a type of kidney stone [63]. Uric acid is obtained from the breakage of purine bases, which are the components of nucleic acids and are excreted in significant amounts in the urine daily [64]. It is claimed that kombucha can decrease kidney calcification and improve one's immune system. Also, the glucuronic acid in this unique beverage is an effective compound in gout treatment. It helps in eliminating toxins waste metabolites and uric acid from the body [65].

Kombucha in Treating AIDS

The causative agent of AIDS is an RNA virus called HIV (human immunodeficiency virus) [66]. The glucuronic acid in kombucha increases the interferon production [67]. Interferons are proteins that release virus-infected host cells that stimulate the immune system and increase the body's resistance [68]. Interferons are the molecules in the body that can act against cells by making them resistant to viral attack [69]. Interferons are particularly resistant to viral infections and are involved in the body's natural immune response, even in the absence of viruses like HIV and cancer [68, 70]. Therefore, this valuable fermented beverage may also be effective in treating AIDS [65].

Energy Production by Kombucha

One of the proven effects of kombucha is its energy production. This fermented drink gives energy to consumers and can be used as an energy drink for sportsmen [71]. Part of this energy comes from consuming compounds such as acetic acid and unfermented sugars in kombucha also kombucha increases the digestion and absorption of nutrients and provides a richer fuel source for cells [67]. Oxalic acid, a by-product of fermentation in kombucha tea helps in adenosine triphosphate production and making energy [15, 72].

Kombucha and Obesity

Kombucha is also believed to play a role in the metabolism and consumption of stored fat in the body. Therefore, consumption of kombucha has been reported as a factor in weight loss in overweight people [72]. Some findings indicate that vitamin C in kombucha can increase beta-oxidation of fatty acids in liver resulting in decreased blood triglyceride levels. Vitamin B3 is another component in kombucha with reducing effects on triglyceride metabolism in liver. Mostly the effect of kombucha on improving obesity is in accordance with acid contents of the extract among which lactic acid is the prominent one [71, 72]. Also, kombucha improves cell functions removes toxins and waste metabolites of the body, and restores the body's freshness [71]. For the above reasons, racing horses and camels are fed with kombucha in some parts of Europe and some Arabian countries [68, 73].

Kombucha and Skin Health

Skin condition is the first and most important aspect of a person's health. The surface layer of the skin that is in contact with the environment is replaced with a new layer after a while [74]. Vitamin B3 in kombucha is the NAD (nicotinamide adenine dinucleotide) precursor which reduces during aging and causes collagen expression failure [75, 76]. The inhibition of the collagenase and elastase were investigated and kombucha (14-day fermentation) inhibited collagenase and elastase at about 33 and 30% respectively at 100 µg/ mL [77]. After SCOBY fermentation, some anti-aging active agents like lactic acid, vitamin B3, and vitamin C are produced which stimulates collagen and hyaluronic acid synthesis [78].

To have healthy, soft, and flexible skin, the cooperation of different parts of the body is essential [79, 80]. Cardiovascular health, which is responsible for delivering nutrients to cells; the health of the lungs, which are the source of oxygen in the blood; healthy kidneys and liver that are involved in the elimination of toxins and waste products from the body and a healthy nervous system that transmits neural messages to the body's organs are all important for having a healthy, clear and smooth skin [81, 82]. Kombucha is involved in increasing digestion efficiency, eliminating toxins and liver health, providing vitamins, free amino acids, and other beneficial compounds, so undoubtedly affects the optimal condition of the skin [83].

Conclusions

Kombucha is a unique drink prepared from black tea with addition of sugar, which leads to formation of a biomass (SCOBY). Since black tea is the main composition, kombucha contains phenolic acids, organic acids, tea catechins, and other polyphenols. Not only type of substrate used, but also other factors such as duration of fermentation, pH, temperature, etc. have important role in compositional formation of kombucha. In this review, the beneficial health effects of valuable kombucha drink are discussed. These interesting properties are based on different amino acids and organic acids produced during fermentation as well as the probiotics in this wonderful beverage. This review article mentioned to some therapeutic effects like antimicrobial, antioxidant, anti-carcinogenic, anti-diabetic, liver detoxification, treatment of gout, AIDS, digestion disorders, gastric ulcers, obesity, and skin improvement are mentioned. Some information about the promotional mechanisms of kombucha in the body is also included. Today there are many probiotic products like yogurt, milk, cheese, and kefir. Their health impact and metabolism are clear. Also, the popularity of kombucha is increasing all over the world due to having numerous health effects.

Although kombucha has many desired effects on human health, the experimental analyses to identify the chemical composition are very important. Finally more advanced chemical and bioactivity research on kombucha would be required.

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Data Availability The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Declarations

Ethics Approval and Consent to Participate Not applicable.

Consent for Publication Not applicable.

Competing Interests The authors declare no competing interests.

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