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Kombucha from Edible Plants as a Functional Beverage with Hypoglycemic Potential: A Review

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Abstract: Diabetes mellitus (DM) is an endocrine disorder caused by a deficiency or ineffective production of insulin by the pancreas, leading to abnormal blood glucose levels. Hypoglycemia is a significant complication of diabetes therapy, referring to the condition or mechanisms that lower blood glucose levels. Kombucha is a functional beverage known for its health benefits, particularly its potential to reduce blood glucose levels. The data collection strategy used in this review was a systematic review. Ten articles were used in this systematic review. Several plants, including sappan wood, *Rhizophora mucronata* leaves, snake fruit, *Cyperus rotundus* L. rhizomes, black tea, green tea, *Solanum betaceum* Cav., strawberry, *Syzygium polyanthum* (Wight) Walp. leaves, and red ginger, have demonstrated potential hypoglycemic effects. The mechanisms involved include inhibition of α-glucosidase enzyme activity, reduction of fasting plasma glucose (FPG), and decreased blood glucose concentration. The presence of secondary metabolites in these plants, combined with the fermentation process involving microorganisms, contributes to their antidiabetic potential through hypoglycemic mechanisms and α-glucosidase inhibition.

Keywords: α-glucosidase; Antidiabetic; Edible Plant; Hypoglycemia; Kombucha.

Introduction

Diabetes mellitus (DM) is a metabolic disease characterised by blood sugar levels above normal thresholds. Diabetes mellitus has a complicated etiology and is a chronic, diverse metabolic disease. It is typified by hyperglycemia, or increased blood glucose levels, which are caused by anomalies in either insulin action or secretion, or both [1]. In this disease, blood glucose levels increase because it cannot be metabolized within the cells. This condition is caused by insufficient insulin production in the pancreas or the inability of body cells to effectively utilize the insulin that is produced [2]. This disease is classified as a global disease with increasing prevalence and impacts the quality of life and health.

In addition to pharmacological interventions, herbs have been used as a source of hypoglycemic agents in recent years. The biological activity of plant products can be used as an alternative medicine to treat diabetes [3]. Nutritional approaches are among the developments in functional foods for the prevention of blood glucose disorders. Kombucha, a fermented beverage produced by a symbiotic culture of bacteria and yeast (SCOBY), has become one of the candidates for functional foods due to its ability to produce microbial metabolites and transform plant compounds that have the potential to affect glucose metabolism [4, 5].

Scientific evidence regarding the antidiabetic effects of kombucha has increased in the last decade. Experimental research on animals reports that kombucha made from tropical fruit substrates such as snake fruit (*Salacca zalacca*) can lower fasting glucose levels in diabetic rats and improve oxidative stress and lipid profiles; some studies have found effects comparable to metformin in certain animal models [6]. In addition, small-scale pilot clinical trials in humans have also shown a decrease in blood sugar after consuming kombucha, although clinical evidence is still limited and requires replication in larger samples [4].

While much of the literature examines tea-based kombucha (black/green tea), the use of local plant substrates (fruits, leaves, flowers, spices) as raw materials for kombucha is becoming increasingly popular and culturally and economically relevant. Local plants are often rich in polyphenols, flavonoids, anthocyanins, and other primary metabolites that can be precursors to bioactive compounds after fermentation. Organic acids and amino acids, vitamins, probiotics, sugars, polyphenols, and antioxidants are among the bioactive substances found in kombucha [7]. Kombucha based on tropical fruits or other local ingredients has been reported to increase antioxidant activity and inhibit carbohydrate-digesting enzymes (α-glucosidase/α-amylase), an in vitro mechanism associated with the potential to reduce glucose absorption [5, 8]. Kombucha bananas showed the greatest inhibition of α-glucosidase activity after 12 days of fermentation, as determined in vitro [9]. Similar results indicate that kombucha fermentation from mulberry leaves can

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significantly improve the α-glucosidase inhibitory [10]. In addition, research conducted by Candra and Darge [11] has shown that honey-enriched sour sop (*Annona muricata*) leaf kombucha exerts positive effects on both lipid profiles and hypoglycemic activity. Similarly, *Sargassum plagiophyllum*-based kombucha demonstrated significant metabolic improvements in type 2 diabetic rat models, including enhanced body weight regulation, reduced fasting blood glucose levels, improved lipid profiles, increased insulin concentrations, and decreased malondialdehyde (MDA) levels [12]. Furthermore, research indicated that the consumption of green tea-based kombucha significantly lowered blood glucose and lipid parameters, specifically LDL, total cholesterol, and triglycerides, while elevating HDL levels in diabetic rats [13].

Research on the chemical characteristics and antioxidant profiles of local plants used as kombucha beverages has been extensively developed. Several indigenous plants have been utilized as kombucha substrates, including siam kintamani orange peel (*Citrus nobilis*), snake fruit (*Salacca zalacca*), butterfly pea flower (*Clitoria ternatea*), and kecombrang flower (*Etlingera elatior*) [14-16]. Previous studies have reported that plant extracts exhibit antidiabetic activity through in vitro, in vivo, and clinical investigations. However, studies focusing on kombucha beverages derived from edible plants with hypoglycemia potential remain very limited. This study reviews kombucha prepared from edible plants with potential antidiabetic properties, particularly as hypoglycemic agents.

Research Methods

The data collection strategy used in this review was a systematic review. This procedure includes locating and compiling material from various previously published scientific publications. The literature search was done in accordance with the Preferred Reporting Items for Systematic Review guidelines. The terms kombucha, edible single plant, hypoglycemia, inhibit α-glucosidase, and blood sugar level reduction are used in journal searches. One edible part of a plant (leaf, rhizome, fruit, seed, etc.) is used to make kombucha.

1. Studies report bioactive compounds present in the kombucha or in the relevant plant substrate.
2. Studies employ in vitro assays (α-glucosidase enzyme inhibition), in vivo experiments (healthy or diabetic animal models such as STZ/alloxan-induced), or human clinical trials (randomized or non-randomized) that report blood glucose outcomes.

As shown in Table 1, the Population, Intervention, Control, and Outcome (PICO) framework was utilized to determine the study's inclusion criteria. After that, the collected articles were selected to ensure they were pertinent to the subject under discussion. Following the identification of pertinent publications, additional analysis was conducted to produce the study findings.

Table 1. PICO Framework

PICO	Description
Population (P)	Kombucha is formulated using a single edible plant (leaf, rhizome, fruit, seed, etc.).
Intervention (I)	Fermentation process by microorganisms SCOBY (yeast, lactic acid bacteria, acetic acid bacteria) on edible plant substrates to produce kombucha drinks with potential hypoglycemia activity, especially blood glucose outcomes.
Comparison (C)	The comparator can be regular tea (non-fermented), normal glucose solution, or conventional antidiabetic drugs (in vivo or clinical trials)
Outcome (O)	Decreased blood glucose, inhibition of α-glucosidase

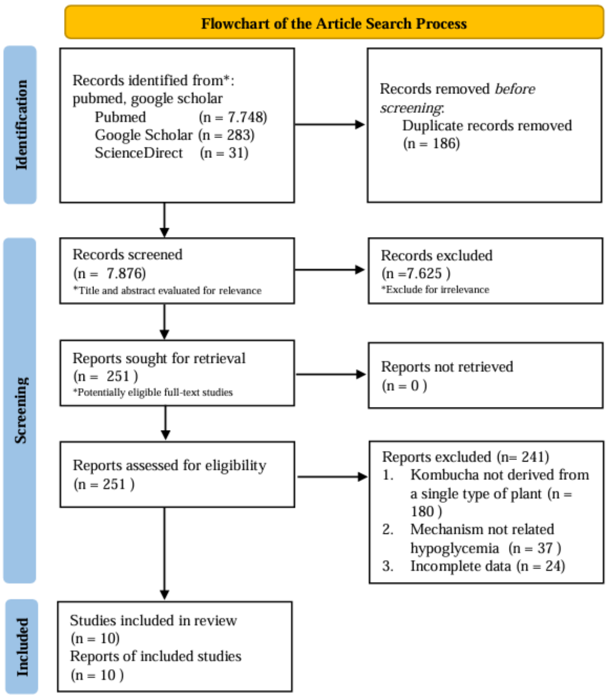

Figure 1. PRISMA Flow Diagram

Results and Discussion

Edible plant-based kombucha beverages produced through fermentation contain a variety of bioactive compounds that confer health benefits. Fermentation serves not only as a traditional preservation method but also as a vital process to ensure food stability and safety. Throughout fermentation, a series of biochemical transformations occur, which can alter the nutritional composition and ultimately influence the functional and sensory properties of the final product [17]. One of the most promising functional potentials of plant-based kombucha is its hypoglycemic activity. Several plant substrates used in kombucha production have been reported to effectively reduce blood glucose levels in both in vivo animal studies and preliminary human trials. A number of edible plant species have also demonstrated significant potential as natural hypoglycemic agents, providing a valuable basis for the development of functional probiotic beverages derived from botanical resources. These include plants rich in polyphenols, flavonoids, and organic acids, which can modulate carbohydrate metabolism, enhance insulin sensitivity, and protect pancreatic β-cell function. Sappan wood [18], *Rhizophora mucronata* leaves [8], snake fruit [6], *C. rotundus* rhizomes [19], black tea [4, 20], green tea [21], dutch eggplant kombucha [22], strawberry [23], *Syzygium polyanthum* (Wight) Walp. leaves kombucha [24], and red ginger (*Zingiber officinale* Roscoe.) kombucha [25]. A comparative summary of edible plant-based kombucha studies with hypoglycemia potential is presented in Table 2 below.

Table 2. Comparative Summary of Edible Plant-Based Kombucha Studies with Hypoglycemia Potential

Name of plant	Duration (days)	Starter Type	Bioactive Compound	In vivo / in vitro models	Hypoglycemia Parameter	Result
Sappan Wood (*Caesalpinia sappan* L.) Kombucha [18]	14	SCOBY	Polyphenols, Flavonoids, and Organic Acids	Male white mice (*Mus musculus* L.) induced with alloxan	Percentage of blood sugar level reduction	A decrease in glucose levels by 82%
Rhizophora mucronata leaves kombucha [8]	14	SCOBY	Flavonoids	Glucosidase inhibition assay	Glucosidase Inhibition Assay	Kombucha tea from *R. mucronata* leaves shows α-glucosidase inhibitory activity
Snake fruit (Salak Suwaru cultivar) kombucha [6]	14	SCOBY	Phenolic, tannin and organic acids	Male Wistar rats induced with streptozotocin	Fasting plasma glucose (FPG) levels	The snake fruit kombucha has a similar effect to metformin in lowering FPG levels. Because of its high concentration of antioxidant chemicals, FPG levels have dropped
Cyperus rotundus L. rhizomes kombucha [19]	14	SCOBY	Flavonoids, phenolic	*Drosophila melanogaster* Oregon-R-C	Alpha-glucosidase activities	When fed kombucha, Drosophila showed notable decreases in alpha-glucosidase activity (reduced by 34.04%, 13.79%, and 11.60% when treated with 100%, 40%, and 10% kombucha, respectively)
Black Tea Kombucha [20]	4,8,12	SCOBY	Flavonoid, tannin, saponin, vitamin and carboxylic acids	White male rats wistar with induced aloksan	Percentage of blood sugar level reduction	A 25% reduction in glucose levels on the 12th day of fermentation
Green Tea Kombucha [21]	14	SCOBY	Phenolic, flavonoids, organic acids	Male wistar rats induced with Streptozotocin (STZ)	Fasting plasma glucose (FPG) levels	A decrease in glucose and insulin levels
Dutch eggplant (*Solanum betaceum* Cav.) kombucha [22]	-	SCOBY	Polyphenol	Male *Mus musculus* were induced with glucose	Blood Glucose Level Reduction	Dutch eggplant kombucha with a dose of 18 ml/kgBB is most effective against the effect of reducing glucose levels in male mice that have been induced with glucose
Strawberry (*Fragaria ananassa*; *Fragaria X ananassa ssp. ananassa*; Kombucha [23]	12	SCOBY	62 potential secondary metabolites (antioxidant and others)	Percentage of α-glucosidase inhibition	Alpha-glucosidase activities	Strawberry kombucha drink shows α-glucosidase inhibitory activity

Syzygium polyanthum (Wight) Walp. Leaves Kombucha [24]	8	SCOBY	Flavonoids, saponins, and tannins	Inhibition of α-glucosidase enzyme activity	α-glucosidase activities	The inhibitory activity against α-glucosidase ranged from 81.05 to 89.41%
Red Ginger (*Zingiber officinale* Roscoe.) Kombucha [25]	14	SCOBY	Phenolic, flavonoids	Inhibition of α-glucosidase enzyme activity	α-glucosidase activities	Inhibition α-glucosidase enzyme activity on the 14th day with 20% inoculum concentration has the highest total acid content of 162.52 %

Kombucha is a fermented beverage produced on scales ranging from small household industries to large commercial operations worldwide [5]. Its growing functional potential and health benefits have led to a steady increase in global consumption. Kombucha is produced through the fermentation of sweetened substrates by a Symbiotic Culture of Bacteria and Yeast (SCOBY), generating a complex mixture of metabolites, including organic acids and polyphenol biotransformation products that enhance the biological activity compared to the original substrate. When the kombucha substrate is replaced with plant-based materials (such as herbs, fruits, seaweeds, or medicinal leaves), the final product often retains or modifies phytochemical profiles relevant to antidiabetic effects. Recent experimental studies, both in vivo and in limited human trials, have demonstrated the tangible potential of such formulations to reduce blood glucose levels and improve metabolic parameters associated with kombucha consumption [4, 26].

One of the primary metabolic mechanisms of kombucha involves the inhibition of carbohydrate-hydrolyzing enzymes (α-glucosidase and α-amylase). Kombucha enriched with polyphenols bio-transformed from plant-based substrates can inhibit these enzymes, thereby slowing the release of glucose from intestinal carbohydrates and reducing postprandial glucose spikes. In vitro assays and animal model studies on plant-based kombucha formulations have reported α-glucosidase inhibitory IC_{50} values within the pharmacologically active range, indicating significant potential for managing blood glucose levels through dietary intervention [8, 19]. In addition, research on kombucha fermentation involving *Camellia sinensis*, *Coffee arabica*, and *Ganoderma lucidum* has demonstrated notable changes in their chemical profiles, accompanied by enhanced α-glucosidase inhibitory activity and antioxidant capacity following fermentation. The results revealed that fermented *G. lucidum* exhibited the strongest in vitro antidiabetic activity, suggesting its role as a promising natural source of hypoglycemic bioactive compounds [27].

Fermentation often enhances the bioavailability of polyphenols or modifies their structural configuration, thereby increasing their antioxidant activity. Reducing oxidative stress helps protect pancreatic β-cells from damage induced by streptozotocin, alloxan, or high-sugar diets, thereby preserving insulin secretion and glucose homeostasis. In vivo studies have demonstrated increased activities of antioxidant enzymes such as superoxide dismutase (SOD) and catalase (CAT), along with decreased levels of malondialdehyde (MDA), following treatment with plant-based kombucha formulations [19, 28].

The SCOBY actively transforms various biochemical components present in kombucha during fermentation [29]. It produces organic acids, such as acetic, gluconic, and lactic acids, as well as other microbial metabolites that can influence systemic metabolism. These metabolites are known to affect glucose absorption, modulate hepatic metabolic pathways, and regulate insulin sensitivity signaling. Moreover, the fermentation process can degrade complex phenolic polymers into smaller, more bioactive monomers. Studies on biotransformation processes have shown that both fermentation duration and SCOBY composition play crucial roles in determining the final metabolite profile and the overall hypoglycemic potential of kombucha [29, 30]. During fermentation, kombucha induces beneficial changes in microbiota composition. Such beneficial changes include an increase in short-chain fatty acid (SCFA)-producing bacteria, which support glucose metabolism and have been associated with improved insulin resistance in animal models. Although clinical evidence in humans remains limited, preclinical data consistently demonstrate microbiota-mediated metabolic effects [31].

Sappan Wood (*Caesalpinia sappan* L) Kombucha

Sappan wood (*Caesalpinia sappan L.*) has been identified as a promising substrate for kombucha production. Sappan wood kombucha exhibited significant antihyperglycemic effects in alloxan-induced diabetic mice [18]. Fermentation with a SCOBY culture enhanced the bioavailability of key bioactive compounds, including brazilin, flavonoids, and phenolic acids. The results showed that administration of a specific dose of sappanwood ethanol extract significantly reduced blood glucose levels in white rats [32]. In addition, sappan wood extract at a dose of 0.50 g/kg body weight was found to be the most effective in lowering glucose levels in hyperglycemic rats [33]. The antioxidant activity of sappan wood kombucha increased proportionally with its concentration, primarily attributed to the presence of phenolic and flavonoid compounds [34, 35]. These metabolites contribute to greater α-glucosidase inhibitory activity and reduced postprandial blood glucose levels. The juice from antioxidant-rich green leafy vegetables has significant antidiabetic potential, mitigating postprandial hyperglycemia in rats [36]. This effect is primarily attributed to inhibition of intestinal α-glucosidase activity and modulation of glucose absorption. α-glucosidase is a key digestive enzyme located in the brush border of the small intestine, responsible for catalyzing the hydrolysis of disaccharides and oligosaccharides into glucose. Inhibition of this enzyme slows down carbohydrate digestion and delays the release of glucose into the bloodstream, thereby reducing postprandial glucose spikes. Bioactive compounds such as flavonoids, phenolic acids, and tannins present in green leafy vegetables interact with the active site of the α-glucosidase enzyme, leading to competitive or non-competitive inhibition. This mechanism effectively reduces intestinal glucose absorption, resulting in a lower, delayed postprandial glycemic response compared to untreated controls.

***Rhizophora mucronata* leaves kombucha**

Tea and kombucha prepared from *Rhizophora mucronata* leaves exhibit strong α-glucosidase inhibitory activity, with IC_{50} values of 0.12 mg/mL for tea and 0.09 mg/mL for kombucha, outperforming the standard drug acarbose (IC_{50} = 2.4 mg/mL) [8]. LC–MS profiling revealed the presence of flavonoid glycosides such as rutin and tetrahydroxyflavone derivatives, which are believed to bind to the enzyme's active site and hinder carbohydrate hydrolysis, thereby reducing postprandial glucose absorption. The study suggests that fermentation slightly enhances the bioactivity of *R. mucronata* leaves, likely due to microbial biotransformation of polyphenols into more active metabolites. These findings align with previous reports showing that mangrove extracts possess potent α-glucosidase inhibitory effects [37]. Collectively, this evidence underscores the potential of *R. mucronata*-based kombucha as a sustainable, plant-derived functional beverage for blood glucose management.

Snake Fruit (Salak Suwaru cultivar) Kombucha

Kombucha prepared from snake fruit (*Salacca zalacca*) exhibits significant antidiabetic and antioxidative activity in in vivo models of streptozotocin-induced diabetic rats [6]. The fermentation process enhances the antioxidant activity of snake fruit kombucha, as indicated by its radical scavenging activity, which is also accompanied by an increase in the levels of phenolic compounds, tannins, and flavonoids [38]. Previous studies have also confirmed that *Salacca zalacca* fruit extract can reduce blood glucose levels in diabetic rats [39].

***Cyperus rotundus* L. Rhizomes Kombucha**

The rhizome of *Cyperus rotundus* L. exhibits antidiabetic potential through alpha-glucosidase inhibition and enhanced antioxidant activity. The fermented extract showed an in vitro α-glucosidase inhibitory IC_{50} of 142.7 ± 5.2 µL/mL and reduced enzyme activity by 34.0% in a Drosophila model using a high-sugar diet. Moreover, the kombucha significantly increased antioxidant enzyme activity and decreased lipid peroxide markers. These results indicate that the treatment can mitigate oxidative stress and improve glucose regulation [19]. A similar study found that the ethanol extract of *Cyperus rotundus* rhizome was able to reduce blood glucose levels and improve the lipid profile in streptozotocin-induced diabetic rats [40]. Moreover, the phenolic compounds present in *Cyperus scariosus* and *Cyperus rotundus* exhibit strong free radical scavenging activity and potent α-glucosidase inhibitory effects [41].

Black Tea Kombucha

Black tea is a common base substrate used in kombucha production. The percentage reduction in blood sugar levels in male rats induced with alloxan decreased after 12 days of kombucha fermentation [20]. Tea polyphenols present in black tea are effective in inhibiting α-glucosidase, potentially useful for controlling postprandial hyperglycemia, or the rise in blood glucose levels after meals [39]. A clinical trial of black tea kombucha administered to adults with type 2 diabetes demonstrated a reduction in fasting blood glucose levels, with the average decrease from 164 to 116 mg/dL [4]. Black tea contains polyphenols that can inhibit the activity of α-glucosidase, sucrase, and α-amylase, depending on the dose [42].

Green Tea Kombucha

Green tea-based kombucha was tested in streptozotocin-induced diabetic rats at three different doses over 14 days. The results showed that the 2.5 mL/kg dose significantly reduced fasting blood glucose and insulin levels compared to diabetic controls, while the 5 mL/kg dose exhibited the strongest effect in lowering oxidative stress and inflammatory biomarkers (MDA, 4-HNE, IL-1β), as well as reducing IL-6 [21]. These findings indicate that green tea kombucha exerts antidiabetic effects by enhancing the antioxidant system and suppressing inflammation. Green tea has also been reported to decrease serum glucose levels and increase total antioxidant capacity in diabetic rats [43]. Green tea polyphenols (TPs) strongly inhibit α-glucosidase activity via a non-competitive inhibition mechanism, with an IC_{50} value of 2.33 µg/mL [44].

Dutch Eggplant (*Solanum betaceum* Cav.) Kombucha

Dutch eggplant (*Solanum betaceum*) is a plant with potential as a functional ingredient for kombucha beverages. Tamarillo kombucha has been shown to reduce blood glucose levels in male rats induced with alloxan [22]. His reduction is associated with the presence of polyphenols, flavonoids, and organic acids formed during fermentation. These compounds are believed to inhibit α-glucosidase activity and enhance antioxidant enzyme activity, thereby reducing glucose absorption and improving insulin sensitivity. The hypoglycemic potential of tamarillo-based kombucha is supported by previous studies investigating tamarillo extracts for their effects on blood glucose levels. Fruit extracts of tamarillo have been reported to lower blood glucose in alloxan-induced male BALB/c mice [45]. Furthermore, tamarillo peel extracts at doses of 0.25, 0.75, and 1.25 g/kg body weight significantly reduced blood glucose levels over 14 days in alloxan-induced male Wistar rats [46].

Strawberry (*Fragaria ananassa*; *Fragaria X ananassa ssp. Ananassa*) Kombucha

Strawberries are among the fruits with the potential to reduce blood glucose levels due to their rich content of bioactive metabolites. Strawberries were processed into a functional beverage with the potential to lower blood sugar levels [12]. Strawberry kombucha was investigated *in vitro* to assess its α-glucosidase inhibitory activity. The strawberry kombucha drink demonstrated α-glucosidase inhibitory effects, with 62 secondary metabolites identified that contribute to various health benefits. Previous studies have also shown that strawberry (*Fragaria × ananassa* Duchesne) extract can reduce blood glucose levels in glucose-induced male white mice [47].

***Syzygium polyanthum* (Wight) Walp. Leaves Kombucha**

Syzygium polyanthum (Wight) Walp. leaves have the potential to be used to produce kombucha and may serve as an alternative treatment for diabetes mellitus. Research has shown that *Syzygium polyanthum* (Wight) Walp. leaf kombucha can inhibit α-glucosidase activity, with inhibition rates ranging from 81.05% to 89.41% [24]. his activity may be attributed to the metabolites contained in the leaves, such as flavonoids, saponins, and tannins. Previous studies have also reported that decoctions of *S. polyanthum* leaves can reduce blood glucose levels in patients with type II diabetes mellitus [48]

Red Ginger (*Zingiber officinale* Roscoe.) Kombucha

Red ginger is a rhizomatous plant known for its numerous health benefits. One of its applications is processing it into kombucha. The study by Filailla, et al. [25] demonstrated that red ginger (*Zingiber officinale* Roscoe) kombucha exhibited α-glucosidase enzyme inhibitory activity on the 14^{th} day, with a 20% inoculum concentration showing the highest total acid content of 162.52%. Research shows that red ginger extract at concentrations of 2%, 5%, and 7% can lower blood glucose levels in aloxane-induced rats [49]. Consumption of red ginger decoction has also been practised to help reduce blood glucose levels. Administration of red ginger decoction has been shown to lower blood glucose levels in patients with diabetes mellitus [50].

Conclusion

Plant-based kombucha has potential as an antidiabetic agent, particularly through hypoglycemic mechanisms. Several plants, including sappan wood, *Rhizophora mucronata* leaves, snake fruit, *Cyperus rotundus* L. rhizomes, black tea, green tea, *Solanum betaceum* Cav., strawberry, *Syzygium polyanthum* (Wight) Walp. leaves, and red ginger, have demonstrated notable hypoglycemic effects. The underlying mechanisms include inhibition of α-glucosidase enzyme activity, reduction of fasting plasma glucose (FPG), and overall decreases in blood glucose concentration.

Author's Contribution

N. T. Wulansari: conceptualized and designed the study, and conducted the research for this review article. N.W.K. Dharmapatni: manuscript editing and refinement. I.A.M. Damayanti: participated in the critical review and final editing of the manuscript.

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References

[1] M. Z. Banday, A. S. Sameer, and S. Nissar, "Pathophysiology of diabetes: An overview," *Avicenna journal of medicine,* vol. 10, no. 04, pp. 174-188, 2020, doi: 10.4103/ajm.ajm_53_20.

[2] G. Roglic, "WHO Global report on diabetes: A summary," *International Journal of Noncommunicable Diseases,* vol. 1, no. 1, pp. 3-8, 2016, doi: 10.4103/2468-8827.184853.

[3] M. U. Rao, M. Sreenivasulu, B. Chengaiah, K. J. Reddy, and C. M. Chetty, "Herbal medicines for diabetes mellitus: a review," *Int J PharmTech Res,* vol. 2, no. 3, pp. 1883-1892, 2010.

[4] C. Mendelson *et al.*, "Kombucha tea as an anti-hyperglycemic agent in humans with diabetes–a randomized controlled pilot investigation," *Frontiers in Nutrition,* vol. 10, p. 1190248, 2023, doi: https://doi.org/10.3389/fnut.2023.1190248.

[5] N. Anantachoke, R. Duangrat, T. Sutthiphatkul, D. Ochaikul, and S. Mangmool, "Kombucha beverages produced from fruits, vegetables, and plants: A review on their pharmacological activities and health benefits," *Foods,* vol. 12, no. 9, p. 1818, 2023, doi: https://doi.org/10.3390/foods12091818.

[6] E. Zubaidah, C. A. Afgani, U. Kalsum, I. Srianta, and P. J. Blanc, "Comparison of in vivo antidiabetes activity of snake fruit Kombucha, black tea Kombucha and metformin," *Biocatalysis and Agricultural Biotechnology,* vol. 17, pp. 465-469, 2019, doi: https://doi.org/10.1016/j.bcab.2018.12.026.

[7] S. Selvaraj and K. Gurumurthy, "An overview of probiotic health booster-kombucha tea," *Chinese herbal medicines,* vol. 15, no. 1, pp. 27-32, 2023, doi: https://doi.org/10.1016/j.chmed.2022.06.010.

[8] Y. E. Puspitasari *et al.*, "α-glucosidase inhibitory activity of tea and kombucha from Rhizophora mucronata leaves," *Beverages,* vol. 10, no. 1, p. 22, 2024, doi: https://doi.org/10.3390/beverages10010022.

[9] H. Mulyani, Y. Maryati, E. Filailla, A. Susilowati, H. Melanie, and S. Budiari, "Alpha-glucosidase and free radical inhibitory activities from local banana (Musa paradisiaca L) fermented by kombucha culture," in *AIP Conference Proceedings*, 2022, vol. 2493, no. 1: AIP Publishing LLC, p. 040003, doi: https://doi.org/10.1063/5.0109970.

[10] L. Ru, "Kombucha fermentation of mulberry leaves and its effect on the content and α-glucosidase inhibitory activity of flavonoid extracts," in *BIO Web of Conferences*, 2023, vol. 72: EDP Sciences, p.

01003, doi: https://doi.org/10.1051/bioconf/20237201003.

[11] A. Candra and H. F. Darge, "Impact of honey-enriched soursop leaves (Annona muricata) kombucha on lipid profiles and hypoglycemic properties: An in-vivo study," *Biocatalysis and Agricultural Biotechnology,* vol. 68, p. 103713, 2025, doi: https://doi.org/10.1016/j.bcab.2025.103713.

[12] A. F. Priambodo, E. Martati, and M. Firdaus, "Hypoglycemic activity of brown seaweed (Sargassum plagiophyllum) kombucha bioactive compound in rat model type-2 of diabetes," in *BIO Web of Conferences*, 2025, vol. 154: EDP Sciences, p. 02009, doi: https://doi.org/10.1051/bioconf/202515402009.

[13] S. A. Hosseini, L. Rasouli, M. Gorjian, and A. Yadollahpour, "A comparative study of the effect of Kombucha prepared from green and black teas on the level of blood glucose and lipid profile of diabetic rats," *International Journal of Pharmaceutical Research & Allied Sciences,* vol. 5, no. 2, 2016.

[14] N. T. Wulansari, A. I. M. Padmiswari, and P. R. Sintyadewi, "Potensi Kulit Jeruk Siam Kintamani (Citrus Nobilis) Sebagai Minuman Probiotik: Analisis Total Bakteri Asam Laktat, Total Yeast, Dan Aktivitas Antimikroorganisme Terhadap Bakteri Penyebab Foodborne Disease," *Berita Biologi,* vol. 24, no. 2, pp. 357–369-357–369, 2025, doi: https://doi.org/10.55981/berita_biologi.2025.10023.

[15] I. A. P. A. Widnyani, W. K. Yoga, P. R. Sintyadewi, and N. K. S. Ariani, "Potential antioxidant kombucha fortified with balinese salak juice (Salacca zalacca Var Amboinensis) from Karangasem District," *Jurnal Biologi Tropis,* vol. 23, no. 1, pp. 411-418, 2023, doi: https://doi.org/10.29303/jbt.v23i1.6128.

[16] P. R. Sintyadewi and P. P. E. Fitriani, "Determination of Antioxidant Activity in Kombucha of Kecombrang Flower (Etlingera elatior) for the Development of Functional Beverages," *Jurnal Pijar Mipa,* vol. 19, no. 2, pp. 343-347, 2024, doi: https://doi.org/10.29303/jpm.v19i2.6616.

[17] S. A. Villarreal-Soto, S. Beaufort, J. Bouajila, J. P. Souchard, and P. Taillandier, "Understanding kombucha tea fermentation: a review," *Journal of food science,* vol. 83, no. 3, pp. 580-588, 2018, doi: https://doi.org/10.1111/1750-3841.14068.

[18] A. Sazali, A. I. Yusuf, H. U. Maritsa, V. G. Sormin, and R. P. Pazira, "Aktivitas Antihiperglikemia Kombucang (Kombucha Kayu Secang (Caesalpinia sappan L.)) Terhadap Mencit (Mus musculus L.) Yang Diinduksi Aloksan," *Berita Biologi,* vol. 24, no. 1, pp. 85–94-85–94, 2025, doi: https://doi.org/10.55981/berita_biologi.2025.8963.

[19] A. Dechakhamphu, N. Wongchum, T. Chumroenphat, A. Tanomtong, S. Pinlaor, and S. Siriamornpun, "In vitro and in vivo evaluation for antioxidant and anti-diabetic properties of Cyperus rotundus L. kombucha," *Foods,* vol. 12, no. 22, p. 4059, 2023, doi: https://doi.org/10.3390/foods12224059.

[20] N. Kristianingtyas, I. R. Hanifah, and I. Iswandi, "The Influence of Fermentation Time of Kombucha Tea on The Decrease of Glucose Level on White Male Rats Wistar With Induced Aloksan," *Jurnal Farmasi Indonesia,* vol. 12, no. 1, pp. 41-49, 2015.

[21] I. Humairah *et al.*, "Green tea kombucha in diabetes management: Dependent doses analysis for anti-diabetic, antioxidant, and anti-inflammatory in STZ-induced rats," *Journal of Medicinal and Pharmaceutical Chemistry Research,* vol. 8, no. 3, pp. 530-544, 2026, doi: 10.48309/jmpcr.2026.525305.1699.

[22] G. S. Pratiwi, M. Gunawan, and M. Saputri, "Test of The Effectiveness of Dutch Eggplant Fruit Kombucha (Solanum betaceum Cav.) on The Decrease In Blood Glucose Levels of Male Mice (Mus musculus) Induced Glucose," *Journal of Pharmaceutical and Medicine,* vol. 1, no. 1, pp. 24-30, 2024, doi: https://doi.org/10.013201/9zyb8895.

[23] A. Pramono *et al.*, "Free radical scavenging, α-amylase, α-glucosidase, and lipase inhibitory activities of metabolites from strawberry kombucha: Molecular docking and in vitro studies," *Pharmacia,* vol. 71, pp. 1-12, 2024, doi: https://doi.org/10.3897/pharmacia.71.e116794.

[24] S. Yuningtyas, M. Alfarabi, Y. Lestari, and H. Noviardi, "The in vitro and in silico study of α-glucosidase inhibition by kombucha derived from Syzygium polyanthum (Wight) Walp. leaves," *HAYATI Journal of Biosciences,* vol. 31, no. 5, pp. 951-963, 2024, doi: https://doi.org/10.4308/hjb.31.5.951-963.

[25] E. Filailla, H. Mulyani, Y. Maryati, and S. Budiari, "The effect of fermentation time and inoculum amount on total sugar, total acid, total flavonoid, total phenol, and inhibition of alpha-glucosidase activity of red ginger kombucha (Zingiber officinale Roscoe)," *Indonesian Journal of Applied Chemistry,* vol. 24, no. 1, pp. 1-8, 2022.

[26] B. Onsun, K. Toprak, and N. Sanlier, "Kombucha Tea: A Functional Beverage and All its Aspects," *Current Nutrition Reports,* vol. 14, no. 1, p. 69, 2025, doi: https://doi.org/10.1007/s13668-025-00658-9.

[27] M. O. Pavlović, M. Stajić, U. Gašić, S. Duletić-Laušević, and J. Ćilerdžić, "The chemical profiling and assessment of antioxidative, antidiabetic and antineurodegenerative potential of Kombucha fermented Camellia sinensis, Coffea arabica and Ganoderma lucidum extracts," *Food & function,* vol. 14, no. 1, pp. 262-276, 2023, doi: https://doi.org/10.1039/D2FO02979K.

[28] J. Grondalska and J. Kolniak-Ostek, "Evaluation of Anti-Inflammatory, Antidiabetic, Antioxidant, and Anticholinergic Activities, as Well as Chemical Composition and Polyphenolic Compounds in Novel SCOBY-Fermented Juices," *Molecules,* vol. 30, no. 9, p. 1940, 2025, doi: https://doi.org/10.3390/molecules30091940.

[29] N. Sanwal, A. Gupta, M. A. Bareen, N. Sharma, and J. K. Sahu, "Kombucha fermentation: Recent trends

in process dynamics, functional bioactivities, toxicity management, and potential applications," *Food chemistry advances,* vol. 3, p. 100421, 2023, doi: https://doi.org/10.1016/j.focha.2023.100421.

[30] W. Liang *et al.*, "Changes and biotransformation mechanism of main functional compounds during kombucha fermentation by the pure cultured tea fungus," *Food Chemistry,* vol. 458, p. 140242, 2024, doi: https://doi.org/10.1016/j.foodchem.2024.140242.

[31] X. Li, N. Tso, S. Huang, J. Wang, Y. Zhou, and R. Liu, "A Comprehensive Evaluation of Microbial Synergistic Metabolic Mechanisms and Health Benefits in Kombucha Fermentation: A Review," *Biology,* vol. 14, no. 8, p. 952, 2025, doi: https://doi.org/10.3390/biology14080952.

[32] S. Saefudin, G. T. Pasaribu, S. Sofnie, and E. Basri, "Effect of Sappan Wood (Caesalpinnia Sappan L) Extract on Blood Glucose Level in White Rats," *Indonesian Journal of Forestry Research,* vol. 1, no. 2, pp. 109-115, 2014, doi: https://doi.org/10.59465/ijfr.2014.1.2.109-115.

[33] N. A. Sakir and J. G. Kim, "The effect of sappan wood extracts in treating diabetes induced in mice," *Makara Journal of Health Research,* vol. 23, no. 2, p. 9, 2019, doi: https://doi.org/10.7454/msk.v23i2.10375.

[34] A. W. M. Yodha, M. Abdillah, A. Indalifiany, E. Elfahmi, and S. Sahidin, "Isolation and identification of antioxidant compounds from methanol extract of sappan wooD (Caesalpinia sappan)," *Jurnal Farmasi Sains dan Praktis,* vol. 7, no. 3, pp. 214-223, 2021.

[35] E. Zubaidah, R. A. Salafy, D. W. Ningtyas, and A. C. D. Wiryawan, "Antioxidant and antibacterial activity of sappan wood (Caesalpinia sappan L.) kombucha," *Advances in Food Science, Sustainable Agriculture and Agroindustrial Engineering (AFSSAAE),* vol. 7, no. 1, pp. 10-19, 2024, doi: https://doi.org/10.21776/ub.afssaae.2024.007.01.2.

[36] A. K. Tiwari *et al.*, "Mitigation of starch and glucose-induced postprandial glycemic excursion in rats by antioxidant-rich green-leafy vegetables' juice," *Pharmacognosy Magazine,* vol. 9, no. Suppl 1, p. S66, 2013, doi: https://doi.org/10.4103/0973-1296.117872.

[37] I. L. Lawag, A. M. Aguinaldo, S. Naheed, and M. Mosihuzzaman, "α-Glucosidase inhibitory activity of selected Philippine plants," *Journal of ethnopharmacology,* vol. 144, no. 1, pp. 217-219, 2012, doi: https://doi.org/10.1016/j.jep.2012.08.019.

[38] E. Zubaidah, F. J. Dewantari, F. R. Novitasari, I. Srianta, and P. J. Blanc, "Potential of snake fruit (Salacca zalacca (Gaerth.) Voss) for the development of a beverage through fermentation with the Kombucha consortium," *Biocatalysis and Agricultural Biotechnology,* vol. 13, pp. 198-203, 2018, doi: https://doi.org/10.1016/j.bcab.2017.12.012.

[39] O. S. Datu, J. S. Lebang, and E. J. Suoth, "Efek Pemberian Ekstrak Buah Salak (Salacca zalacca) dalam menurunkan kadar glukosa darah pada tikus model Diabetes melitus," *Jurnal MIPA,* vol. 12, no. 1, pp. 30-33, 2023, doi: https://doi.org/10.35799/jm.v12i1.44267.

[40] P. Singh, R. L. Khosa, G. Mishra, and K. K. Jha, "Antidiabetic activity of ethanolic extract of Cyperus rotundus rhizomes in streptozotocin-induced diabetic mice," *Journal of Pharmacy and Bioallied Sciences,* vol. 7, no. 4, pp. 289-292, 2015, doi: 10.4103/0975-7406.168028.

[41] L. Kakarla *et al.*, "Free radical scavenging, α-glucosidase inhibitory and anti-inflammatory constituents from Indian sedges, Cyperus scariosus R. Br and Cyperus rotundus L," *Pharmacognosy Magazine,* vol. 12, no. Suppl 4, p. S488, 2016, doi: https://doi.org/10.4103/0973-1296.191467.

[42] Y. Isono, H. Watanabe, M. Kumada, T. Takara, and S.-i. Iio, "Black tea decreases postprandial blood glucose levels in healthy humans and contains high-molecular-weight polyphenols that inhibit α-glucosidase and α-amylase in vitro: a randomized, double blind, placebo-controlled, crossover trial," *Functional Foods in Health and Disease,* vol. 11, no. 5, pp. 222-237, 2021, doi: https://doi.org/10.31989/ffhd.v11i5.791.

[43] F. Haidari, K. Omidian, H. Rafiei, M. Zarei, and M. M. Shahi, "Green tea (Camellia sinensis) supplementation to diabetic rats improves serum and hepatic oxidative stress markers," *Iranian journal of pharmaceutical research: IJPR,* vol. 12, no. 1, p. 109, 2013.

[44] X. Yang and F. Kong, "Evaluation of the in vitro α-glucosidase inhibitory activity of green tea polyphenols and different tea types," *Journal of the Science of Food and Agriculture,* vol. 96, no. 3, pp. 777-782, 2016, doi: https://doi.org/10.1002/jsfa.7147.

[45] A. Rosadi, "Pengaruh Ekstrak Bbuah Terung Belanda (Solanum Betaceum Cav.) terhadap Kadar Gula Darah Mencit Jantan Galur Balb/C yang Diinduksi Aaloksan," *Jurnal Farmasi Udayana,* vol. 7, no. 2, pp. 63-67, 2018.

[46] R. Sirumapea, N. Suhartatik, N. Suhartatik, Y. Wulandari, and Y. Wulandari, "Pemanfaatan Ekstrak Kulit Terong Belanda (Solanum betaceum) Sebagai Antidiabetes Pada Tikus Wistar Jantan Yang Diinduksi Aloksan," *Jurnal Teknologi Dan Industri Pangan,* vol. 5, no. 1, 2020, doi: https://doi.org/10.33061/jitipari.v5i1.3713.

[47] A. A. Rasyad and S. Nurhidyah, "Pengaruh ekstrak buah stroberi (Fragaria x ananassa Duchesne) terhadap penurunan kadar gula darah mencit putih jantan yang diinduksi glukosa," *Jurnal Ilmiah Bakti Farmasi,* vol. 2, no. 1, 2017.

[48] R. A. E. Wigati and D. K. Rukmi, "Pengaruh Rebusan Air Daun Salam (Zysygium Polyanthum) Terhadap Penurunan Kadar Glukosa Darah Penderita Diabetes Mellitus Tipe II," *Jurnal Keperawatan Notokusumo,* vol. 9, no. 2, pp. 41-51, 2021.

[49] S. T. Dewi and J. Jumain, "The Effectiveness Of Red Ginger Extract (Zingiber Officinale Var. Rubrum) On Decreased Blood Glucose Levels In Mice (Mus Musculus)," *Indonesian Health Journal,*

vol. 2, no. 1, pp. 16-21, 2023, doi: https://doi.org/10.58344/ihj.v2i1.23.

[50] F. Dewi and S. Afrioza, "Pengaruh Air Rebusan Jahe Merah (Zingiber Officinale Var. Rubrum) Terhadap Kadar Gula Darah Pasien Diabetes Melitus Di Desa Mekarjaya," *Nusantara Hasana Journal,* vol. 2, no. 4, pp. 148-155, 2022.