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Plant-Based Probiotic Beverages in Preventing the Growth of Foodborne Pathogenic Bacteria: A Review

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Abstract: Foodborne illnesses are mostly caused by bacteria. Bacteria, including Escherichia coli, Salmonella sp., Shigella sp. and Staphylococcus aureus, are the most common causes of foodborne diseases. One alternative to reduce the risk of infection from bacteria that cause foodborne diseases is the consumption of probiotic beverages, which has become a natural alternative in improving digestive health and endurance. One type of probiotic drink that is gaining increasing attention is plant-based kombucha tea. Plant parts that can be used as kombucha tea are fruits, leaves, and flowers and have antibacterial activity with various categories of inhibition zone strength. This research uses a systematic review and collects relevant articles, with 14 articles as the main reference. The analysis found that salak Bali fruit, pineapple honey fruit, belimbing wuluh fruit, tea leaves, soursop leaves, telang flowers, gardenia flowers, and red seaweed have the potential as a probiotic kombucha tea drink that can inhibit the growth of pathogenic bacteria that cause foodborne diseases. The categories of inhibition zones produced ranged from weak to very strong, with inhibition zone diameters ranging from 4.20 mm to 24.7 mm. The optimal zone of inhibition of this probiotic drink is influenced by the plant parts used, the length of fermentation, the type of substrate, the test method and the type of bacteria. Plant-based probiotic beverages show effective antibacterial activity against foodborne pathogens and offer valuable insights into microbial interactions and sustainable food biotechnology in scientific learning.

Keywords: Antibacterial; Foodborne Pathogens; Kombucha Tea; Probiotic Beverages.

Introduction

Food contamination has become a serious global health issue, posing great challenges to the food industry. Foodborne illnesses are mostly caused by bacteria. Bacteria, including *Escherichia coli*, *Salmonella* sp., *Shigella* sp., and *Staphylococcus aureus* are the most common causes of foodborne diseases [1, 2].

Infections from these bacteria can cause a variety of health problems, ranging from mild diarrhoea to life-threatening systemic infections. *E. coli*, especially pathogenic strains such as *E. coli* O157:H7, can cause bloody diarrhea and serious complications such as haemolytic-uremic syndrome [3]. Meanwhile, *S. aureus* produces enterotoxins that are resistant to heating and can cause food poisoning with symptoms of vomiting and diarrhea within a short time after consumption of contaminated food [4]. Other bacteria, such as *Salmonella* sp. are one of the main causes of gastroenteritis and typhoid fever, with high infection rates due to the consumption of unhygienic food [5]. *Shigella* sp. is a highly contagious bacterium and is the main cause of bacillary dysentery, which is characterized by bloody diarrhea and severe dehydration [6].

To reduce the risk of infection from bacteria that cause foodborne diseases, the consumption of probiotic drinks has become a natural alternative in improving digestive health and immunity. One type of probiotic drink that is gaining increasing attention is plant-based kombucha tea. Kombucha is a traditional beverage manufactured from fermenting tea (*Camellia sinensis* (L.) Kuntze) with a symbiotic culture of bacteria and yeasts (SCOBY) in a sweet medium under aerobic conditions for several days [7]. Milk-based probiotic drinks such as yogurt and kefir have long been consumed for their beneficial bacteria content that can improve gut health. However, plant-based kombucha tea has several advantages over dairy-based probiotic drinks, especially in terms of availability to various consumer groups, bioactive compound content, and higher potential antibacterial effects. Natural antimicrobial agents have been identified in a variety of biological sources, including plants, microorganisms and animals. Plants, particularly spices, herbs, fruits, and vegetables, are a major source of phenolic compounds, essential oils, and organic acids that have antimicrobial activity against human pathogens [8]. Fruits and vegetables are widely recognized as major sources of nutrients, antioxidants, vitamins, dietary fibre, minerals, and bioactive molecules. These ingredients make fruits and vegetables an essential part of a balanced diet, with a variety of proven benefits for human health [9]. Milk-based probiotic drinks contain lactose, which may cause gastrointestinal distress for individuals with lactose intolerance. In contrast, fruit-based kombucha tea is completely lactose-free, making it more suitable for individuals with dairy allergies, lactose intolerance, as well as for those on a vegan diet [10].

Fruit-based kombucha tea contains various organic acids such as acetic acid, gluconic acid, and lactic acid that have stronger antibacterial effects than milk-based probiotic

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drinks [11]. In the fermentation process, lactic acid bacteria and yeast in kombucha also produce secondary metabolites such as glucoronate that help in detoxifying the body [12]. Fruit-based kombucha has a fresher flavor with a natural carbonation sensation produced during fermentation. This makes kombucha more easily accepted by various consumer groups compared to yogurt or kefir, which have a more sour and thick taste and texture [11].

Utilization of plant parts, such as kombucha, in addition to the fruit, other parts of the plant are also widely researched to be developed as probiotic drinks. Various plant parts, such as flowers and leaves, can have potential as probiotic drinks. With the increasing need for non-dairy-based probiotic beverage alternatives, plant-based kombucha tea offers various advantages in terms of nutritional content, antibacterial activity, and affordability for various consumer groups.

This article examines plants that have the potential as probiotic beverages, such as kombucha tea, which can inhibit bacteria. The combination of probiotic content, organic acids, and bioactive compounds in fruit-based kombucha tea makes it a potentially effective drink in inhibiting the growth of bacteria that cause foodborne diseases. Therefore, further research on the effectiveness of kombucha tea in preventing pathogenic bacterial infections is essential to support its development as an alternative functional beverage in the future.

Research Methods

The data collection approach used in this review is a literature review. This process involves searching for and collecting articles from various previously published scientific journals. The literature search was conducted in accordance with the Preferred Reporting Items for Systematic Review guidelines. The keywords used for journal searches include *Probiotic Beverages*, *Kombucha Tea*, *Plant Extracts*, and *Antibacterial*. Once the articles were identified, they were analyzed and synthesized based on the following inclusion criteria:

1. Plants that can be utilized as probiotic beverages,
2. Plants used in the production of kombucha tea,
3. Kombucha tea that has been tested for antibacterial activity against *Staphylococcus aureus*, *Escherichia coli*, *Salmonella sp.*, or *Shigella sp.* using the diffusion method, and
4. Contains a single plant type.

To establish the inclusion criteria for this study, the Population, Intervention, Control, and Outcome (PICO) framework was used, as described in Table 1. The obtained articles were then selected to ensure their relevance to the discussed topic. After identifying the relevant articles, further analysis was conducted to obtain research results.

Figure 1 illustrates the process flow of article selection in this study. At the identification stage, 1,350 articles were found from PubMed, 1.058 from Google Scholar, and 32 from other sources, resulting in a total of 2.440 articles. After removing 10 duplicate articles, 2.430 unique articles remained and proceeded to the screening stage. During the screening stage, 2.330 articles were assessed based on their titles and abstracts. A total of 2.305 articles were excluded due to irrelevance. At the eligibility stage, 25 full-text articles were reviewed to assess their suitability. Of these, 11 articles did not meet the criteria. Finally, 14 studies were included for the purpose of the review.

Table 1. PICO Framework

Population (P)	Plants that can be developed into probiotic beverages, such as kombucha tea.
Intervention (I)	Antibacterial testing against *Staphylococcus aureus*, Escherichia coli, Staphylococcus aureus, Salmonella sp., or *Shigella sp.* on the developed plants.
Comparison (C)	Comparison among various plants used for kombucha tea production
Outcome (O)	The ability of a plant developed into kombucha tea to inhibit the growth of bacteria such as *Staphylococcus aureus*, *Escherichia coli*, *Staphylococcus aureus*, *Salmonella* sp., and *Shigella* sp.

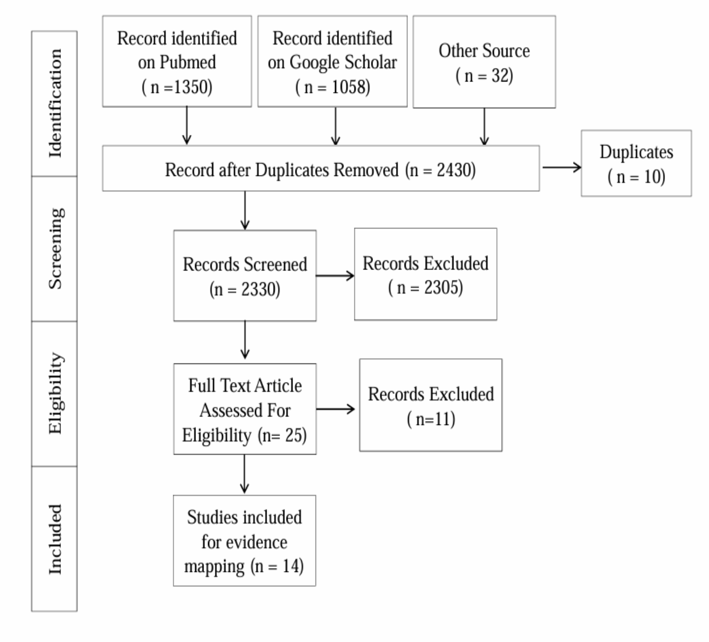

Figure 1. PRISMA Flow Diagram

Results and Discussion

The development of nondairy probiotic beverages has received increasing attention in scientific research. Various types of fruits and vegetables are used as basic ingredients in the production of non-dairy probiotic beverages, such as kombucha tea. The fermentation process that occurs in these beverages causes significant changes in their chemical and microbiological characteristics, including increased antimicrobial activity. The review showed that plant-based probiotic beverages, such as kombucha tea, are increasingly in demand by the public. The presence of lactic acid bacteria and yeast cultures in probiotic beverages contributes to changes in their characteristics as well as enhancement of their functional benefits. Probiotic drinks containing lactic acid bacteria are known to inhibit the growth of various pathogenic bacteria that cause foodborne diseases, such as *E. coli, S. aureus*, *Salmonella* sp., and *Shigella* sp.

Several plants have potential as ingredients in making probiotic kombucha tea that can inhibit the growth of bacteria that cause foodborne illness. Among these, tea leaves (*Camellia sinensis*) are known to be effective against *E. coli*, *E. coli* O157:H7, *Shigella dysenteriae*, and *Salmonella typhi* [13]. In addition, telang flowers (*Clitoria ternatea* L.) [14-16] and soursop leaves (*Annona muricata* L.) can inhibit the growth of *S. aureus*, *E. coli*, and *Salmonella typhi* [17, 18]. Balinese salak fruit (*Salacca zalacca*) [19, 20], kecombrang flower (*Etlingera elatior*) [21], roselle flower (*Hibiscus sabdariffa* L.) [22], gardenia flower (*Gardenia jasminoides*) [23] Subang honey pineapple (*Ananas comosus*) [24], and red seaweed (*Eucheuma spinosum*) [25] are known to inhibit *S. aureus and E. coli* bacteria. Meanwhile, kombucha made from belimbing wuluh (*Averrhoa bilimbi* L.) also has an inhibitory effect on *E. coli* bacteria [26].

Table 2. Antibacterial Activity of Various Plants with Potential as Probiotic Kombucha Tea Beverages

Plant Name	Fermentation Duration (days)	Starter Type	Substrate Type	Highest Inhibition Treatment	Antibacterial Method	Bacteria	Average Inhibition Zone (mm)
Tea Leaves (*Camellia sinensis*): Green Tea [13]	15	Consortium culture combining yeast and acetic acid bacteria	Sucrose	15-day fermented tea without any treatment	Well diffusion	*E.coli* *E. coli O157:H7* *Shigella dysenteriae* *Salmonella typhi*	24.7 24.3 21.7 23.7
Tea Leaves (*Camellia sinensis*) : Oolong tea [13]	15	Consortium culture combining yeast and acetic acid bacteria	Sucrose	15-day fermented tea without any treatment	Well diffusion	*E.coli* *E. coli O157:H7* *Shigella dysenteriae* *Salmonella typhi*	23.7 20.3 19.3 24.7
Tea Leaves (*Camellia sinensis*) : Black tea [13]	15	Consortium culture combining yeast and acetic acid bacteria	Sucrose	15-day fermented tea without any treatment	Well diffusion	*E.coli* *E. coli O157:H7* *Shigella dysenteriae* *Salmonella typhi*	21.0 21.3 21.0 20.0
Telang flower (*Clitoria ternatea* L) [14]	12	SCOBY	Tropicana Slim Sugar	40% sugar concentration	Disc diffusion	*S.aureus* *E.coli*	22.60 21.02
Telang flower (*Clitoria ternatea* L) [15]	14	SCOBY	Palm sugar	40% sugar concentration	Disc diffusion	*Salmonella typhi*	18.23
Telang flower (*Clitoria ternatea* L) [16]	14	SCOBY	Honey	40 % honey concentration	Disc diffusion	*S.aureus* TCC 2593 *E.coli* ATCC 25922	24.16 21.13
Soursoup leaf (*Annona muricata* L) [17]	12	Kombucha starter	Granulated sugar	20 % sugar concentration	Well diffusion	*S.aureus* *E.coli*	17.08 16.28
Soursoup leaf (*Annona muricata* L) [18]	14	SCOBY	Granulated sugar	100% kombucha concentration	Well diffusion	*E.coli* *Salmonella typhi*	12.30 10.36
Salak Bali Fruit (*Salacca zalacca*) [19]	18	SCOBY	Granulated sugar	15 day fermentation	Disc diffusion	*E.coli*	8.13
Salak Bali Fruit	18	SCOBY	Granulated sugar	15 day fermentati	Well diffusion	*S.aureus*	8.85

(*Salacca zalacca*) [20]				on			
Kecombrang flower (*Etlingera elatior*) [21]	12	SCOBY	Granulated sugar	40% sugar concentration	Disc diffusion	*E.coli* *S.aureus*	10.30 14.00
Roselle flower (*Hibiscus sabdariffa* L) [22]	7	SCOBY	Granulated sugar	40 % roselle concentration (g/v)	Disc diffusion	*E.coli* *S. aureus*	6.50 5.00
Gardenia flower (*Gardenia jasminoides*) [23]	14	SCOBY	Granulated sugar	40% sugar concentration	Disc diffusion	*E.coli* *S.aureus*	12.07 15.36
Honey Pineapple Fruit Subang (*Ananas comosus*) [24]	14	SCOBY	Granulated sugar	35% sugar concentration	Disc diffusion	*E.coli* *S.aureus*	17.17 24.16
Red seaweed (*Eucheuma spinosum*) [25]	14	SCOBY	Granulated sugar	40% sugar concentration	Disc diffusion	*E.coli* *S.aureus*	10.35 13.30
Belimbing Wuluh fruit (*Averrhoa bilimbi* L) [26]	14	Kombucha starter	Granulated sugar	100% kombucha concentration	Well diffusion	*E.coli*	4.20

Kombucha is a fermented sweet tea that involves a symbiotic culture between bacteria and yeast, abbreviated as SCOBY. This culture is also known as tea mold, cellulose pellicle, or microbial consortium [27]. Yeast in SCOBY is known to be a major contributor to ethanol production. Furthermore, the ethanol produced is converted into acetic acid through oxidation by acetic acid bacteria [28]. The production of more acetic acid and ethanol prevents pathogenic microbial contamination, as it acts as an antimicrobial agent [29].

Lactic acid bacteria grow during the fermentation process. Sugar is the substrate used by lactic acid bacteria to produce lactic acid during the fermentation process. In the early stages of fermentation, it is thought that the bacteria undergo an adaptation phase to adjust to their environment. After that, they enter a logarithmic phase where bacterial growth increases rapidly thanks to the availability of abundant nutrients and favorable environmental conditions. In the exponential phase, microbial growth takes place rapidly due to an increase in the number of cells triggered by adequate nutrition and a conducive environment [30]. The yeast decomposes sucrose into glucose and fructose with the help of the enzyme invertase, then produces ethanol. Meanwhile, acetic acid bacteria utilize glucose to produce gluconic acid and use ethanol in the production of acetic acid [31]. The accumulation of acidic compounds during fermentation causes a decrease in the ph of the solution, thereby increasing its acidity and affecting antibacterial activity [29].

In this review, antibacterial testing of plants as probiotic drinks is using either the disc diffusion method or the well diffusion method. The diffusion method is a commonly used technique in the qualitative analysis of antibacterial activity and serves to measure the diameter of the inhibition zone of a bacterium against a particular solvent. The result is indicated by the presence or absence of a clear area around the disc paper, which indicates a zone of inhibition in bacterial growth [32]. The working principle of the diffusion method is the diffusion of antibacterial compounds into the solid medium in which the test microbes have been inoculated. The diffusion method can be the disk diffusion method, agar well diffusion method, agar plug diffusion method [32]. Antibacterial inhibition can be categorized based on the diameter of the inhibition zone, namely, ≤5 mm is included in the weak category, 6-10 mm is classified as moderate, 11-20 mm is considered strong, and ≥21 mm is classified as very strong [33]. Plant parts commonly used as probiotic beverage ingredients include fruits, flowers, and leaves. These plant organs contain various secondary metabolite compounds that play a role in supporting health, especially as antibacterial agents.

Tea Leaves (*Camellia sinensis*)

Kombucha tea is a common nondairy probiotic beverage produced from the fermentation of tea leaves. Research on kombucha tea made from green tea, oolong tea, and black tea with a starter culture that is a symbiotic culture of acetic acid bacteria, including *Acetobacter* *xylinum*, and yeast cells [13]. The antimicrobial activity of kombucha tea after 15 days of fermentation was analyzed using the agar well diffusion method. The results showed that tea fermented from various types of tea leaves, namely green tea, oolong tea, and black tea, had an average inhibition against *E. coli* of 24.7 mm, 23.7 mm, and 21.0 mm, respectively, which was classified as very strong. Meanwhile, against *E. coli* O157:H7, the average inhibition produced was 24.3 mm, 20.3 mm, and 21.3 mm. In addition, tea fermentation also showed the highest inhibition against *S. typhi*, with an average of 23.7 mm, 24.7 mm, and 20.0 mm in green tea, oolong tea, and black tea, respectively. The green tea and the oolong were categorized as very strong, while the black tea was classified as strong. Phytochemical screening of green tea leaves shows that both wet and dry green tea contain phenol compounds, flavonoids, alkaloids, tannins, saponins, steroids, and glycosides [34].

Telang Flowers (*Clitoria ternatea* L.)

Kombucha made from telang flowers (*Clitoria ternatea* L.) has a high flavonoid content, which is known to have an effect as an antioxidant [35]. In addition, fermentation of telang flowers into kombucha increases antibacterial activity, making it a functional drink that has the potential to support health aspects [14]. Antibacterial activity using the well diffusion method [36]. The results show that 40% concentration is the best concentration of stevia sugar in kombucha fermentation of telang flowers to inhibit the growth of *S. aureus* bacteria, as a group of gram-positive bacteria, and *E. coli*, which is classified as gram-negative bacteria. Telang flower kombucha tea has a very strong potential in producing inhibition zones on *S. aureus* and *E. coli* bacteria [14, 16]. While telang flower kombucha tea with variations in palm sugar concentration can inhibit the growth of *S. typhi* bacteria with a strong category [15]. Kombucha contains a symbiosis of bacteria and yeast that produces secondary metabolite compounds, thus increasing its effectiveness as an antibacterial agent against pathogens that work by damaging the peptidoglycan component of the cell wall of Gram-negative and Gram-positive bacteria [36].

Soursop (*Annona muricata* Linn.)

Soursop (*Annona muricata* Linn.) is one of the plants that has the potential to be utilized as raw material in the manufacture of probiotic drinks, especially in the leaves. Research showed that soursop leaf kombucha with a sugar concentration of 20% had the most optimal antibacterial activity, with an inhibition zone against *E. coli* of 16.28 mm and against *S. aureus* of 17.08 mm, with a strong category [17]. In addition, soursop leaf kombucha with a kombucha concentration of 100% effectively inhibited *E. coli* with an inhibition zone of 12.3 mm, with the strong category, while at a concentration of 50%, it was able to inhibit *Salmonella typhi* with an inhibition zone of 8.47 mm, which is in the medium category [18].

The ability of soursop leaf kombucha to inhibit the growth of pathogenic bacteria is attributed to the content of bioactive compounds, especially organic acids such as acetic acid. Acetic acid is known to be effective in inhibiting the growth of bacteria from both the gram-negative and the gram-positive groups [37]. The antibacterial activity of soursop leaf kombucha is also shown by research that kombucha with a fermentation time of 7 days is the best time to produce antibacterial potential of *E. coli*, with a strong category [38].

Salak Bali (*Salacca zalacca*)

Probiotic drinks based on Salak Bali (*Salacca zalacca*) were effective in inhibiting the growth of *E. coli* [19]. Optimal antibacterial activity was observed on the 15^{th} day of fermentation, with an inhibition zone of 8.13 mm, which was categorized as moderate. In addition, Balinese salak fruit-based probiotics also have the ability to inhibit the growth of *S. aureus*, with inhibition zones ranging from 6.12 mm to 8.85 mm, classified as a moderate category [20]. The Symbiotic Culture of Bacteria and Yeasts (SCOBY) isolate contained in the probiotic drink plays a role in the antibacterial activity, in addition to the contribution of natural phytochemicals contained in salak fruit. SCOBY, which is a symbiosis between bacteria and yeast, contains lactic acid bacteria that can inhibit the growth of various other pathogenic bacteria [39].

Kecombrang flower (*Etlingera elatior*)

Kecombrang flowers can be utilized in the production of kombucha tea [21]. The results showed that kombucha fermentation of kecombrang flowers with a sugar concentration of 40% was the optimal condition in inhibiting the growth of *S. aureus* and *E. coli,* with a moderate inhibition category, with inhibition zone diameters of 14 mm and 10.3 mm, respectively. The antibacterial activity test was conducted using the disc diffusion method. The effectiveness of this bacterial inhibition is attributed to the phytochemical content contained in kecombrang flower kombucha tea, such as flavonoids, alkaloids, steroids/terpenoids, and saponins.

Belimbing wuluh (*Averrhoa bilimbi*)

The fruit of Belimbing wuluh (*Averrhoa bilimbi*) has the potential to be developed into kombucha tea. Fermentation of belimbing wuluh was carried out for 14 days using a kombucha starter [26]. The results showed that at the highest concentration (35%), belimbing wuluh kombucha tea was able to inhibit the growth of *E. coli* with an inhibition zone of 0.42 cm or 4.2 mm, which was classified as weak. The increase in kombucha concentration is directly proportional to the amount of solute produced, thus expanding the inhibition zone, which is characterized by the formation of clear areas around the wells. Phytochemical analysis indicates that belimbing wuluh (*Averrhoa bilimbi* L.) leaves contain bioactive compounds, including alkaloids, flavonoids, phenolics, saponins, tannins, and steroids [40].

Roselle flower (*Hibiscus sabdariffa* L.)

Roselle flower (*Hibiscus sabdariffa* L.) is one of the flowers that is used in kombucha tea. Antibacterial inhibition on *S. aureus* and *E. coli* bacteria of 5.00 mm and 6.50 mm, respectively, from roselle flower kombucha tea

[22]. The inhibition zone is classified as the weak category; this is possible because it is caused by the relatively short fermentation time, so that the fermentation process has not run optimally. The fermentation process that has not been optimized will affect the production of organic acid, acetic acid.

Gardenia flower (*Gardenia jasminoides*)

The antibacterial activity of gardenia flower (*Gardenia jasminoides*) fermentation against *E. coli and S. aureus* is attributed to the presence of bioactive compounds, including alkaloids, flavonoids, tannins, saponins, and triterpenoids, which are widely known to have antibacterial effects. Fermentation using SCOBYs contributes to the increased production of organic acids, such as acetic acid, which leads to a decrease in the pH of the environment and creates conditions less favorable for the growth of pathogenic bacteria. In addition, the fermentation process can optimize the availability and effectiveness of antibacterial compounds through the biotransformation mechanism of phytochemical compounds. Kombucha fermentation made from gardenia flowers with 40% sugar concentration showed significant antibacterial activity against *E. coli* and *S. aureus*, with an average inhibition zone diameter of 12.07 mm and 15.36 mm, respectively, which is included in the strong category [23].

Red seaweed (*Eucheuma spinosum*)

The data obtained showed that fermentation of red seaweed (*Eucheuma spinosum*) for 14 days using SCOBY as a starter and sugar as a substrate produced antibacterial activity against *E. coli* and *S. aureus*. The 40% sugar concentration produced the highest inhibition zone, with a diameter of 10.35 mm for E. coli and 13.30 mm for S. aureus, respectively [25]. The resulting inhibition is included in the strong category. This antibacterial effectiveness can be attributed to the content of secondary metabolites in *E. spinosum*, such as phenols, flavonoids, alkaloids, and saponins, which have been known to have antibacterial activity [41] . During the fermentation process, SCOBYs produce various bioactive compounds, including organic acids such as acetic acid and lactic acid, which contribute to lowering the pH of the medium. This decrease in pH creates an environment that is not conducive to the growth of pathogenic bacteria [42].

Honey Pineapple Fruit Subang (*Ananas comosus*)

Honey Pineapple fruit, with its distinctive sweet and sour flavor and richness in bromelain enzymes and antioxidants, is an attractive choice as an ingredient in kombucha tea. Subang honey pineapple fruit kombucha can be categorized as a broad-spectrum antibacterial that has proven potential in inhibiting the growth of bacteria such as *S. aureus* and *E. coli* by 24.16 mm (very strong category) and 17.17 mm (strong category) at a concentration of 35% [24]. The results of phytochemical screening in the study stated that the pineapple peel pulp of Subang honey contains alkaloids, flavonoids, saponins, and tannins.

Conclusion

Based on a literature review of 14 articles, various plants show potential as kombucha tea probiotic drinks, which can inhibit the growth of bacteria that cause foodborne diseases such as E. coli, S *aureus*, *Salmonella* sp., and *Shigella* sp. The categories of inhibition zones produced varied from weak to very strong, with diameters ranging from 4.20 mm to 24.7 mm. This study concludes that plant-based probiotic beverages are effective in inhibiting the growth of foodborne pathogenic bacteria through biological mechanisms such as the production of antimicrobial compounds. In the context of scientific learning, these findings enhance the understanding of microbial interactions, applications of food biotechnology, and the importance of natural ingredient-based innovations to support sustainable food safety and public health.

Author’s Contribution

Nadya Treesna Wulansari designed and conducted research for this review article.

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