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Effect of yacon (*Smallanthus sossnchifolius*) tuber extract addition on chemical and organoleptic characteristics of green tea kombucha

Pengaruh penambahan sari umbi yakon terhadap karakteristik kimia dan organoleptik kombucha teh hijau

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Abstract

Kombucha is a fermented beverage produced from tea, sugar, and a symbiotic culture of microorganisms. Yakon tubers have a natural sweetness and contain phenolic compounds, fructooligosaccharides, and inulin, which function as natural prebiotics. However, studies on the incorporation of yakon tubers into green tea kombucha are limited. This study aimed to evaluate the effect of yakon tuber extract on the chemical and organoleptic characteristics of green tea kombucha. A true experimental design with a Completely Randomized Design was applied using four formulations: F0 (0%), F1 (10%), F2 (20%), and F3 (30%). The parameters analyzed included pH, total sugar content (DNS method), total flavonoid content (UV–Vis spectrophotometry), and sensory evaluation by 30 panelists, carried out for 1 month at Universitas Brawijaya. Data were analyzed using one-way ANOVA/Kruskal–Wallis/Mann–Whitney and Duncan's Multiple Range Test (DMRT), as appropriate. The results showed that the addition of yakon extract reduced the total sugar content (p=0.015) and increased the total flavonoid content (p=0.000). The final pH values were within a safe range (2.54–2.62), with no significant differences in the sensory attributes (p>0.05). Yakon tubers support microbial growth during fermentation. Formulation F3 (30%) was identified as the best treatment based on its acceptable pH, lower sugar content after dilution, and highest panelist preference.

Keywords: Kombucha, green tea, yacon tuber

Abstrak

Kombucha merupakan minuman fermentasi hasil pencampuran teh, gula, dan kultur simbiotik. Umbi yakon memiliki rasa manis alami serta kaya senyawa fenolik sebagai antioksidan, fruktooligosakarida (FOS), dan inulin yang berperan sebagai prebiotik. Namun, penelitian terkait kombinasi teh hijau dan umbi yakon masih terbatas. Penelitian ini bertujuan menganalisis pengaruh penambahan sari umbi yakon terhadap karakteristik kimia dan organoleptik kombucha teh hijau. Penelitian menggunakan desain true experimental dengan Rancangan Acak Lengkap (RAL) empat formulasi: F0 (0%), F1 (10%), F2 (20%), dan F3 (30%). Parameter yang dianalisis meliputi pH, kadar gula total (metode DNS), flavonoid total (UV–Vis), serta uji organoleptik oleh 30 panelis yang dilakukan selama 1 bulan di Universitas Brawijaya. Data dianalisis menggunakan ANOVA/Kruskal-Wallis/Mann-Whitney dan DMRT. Hasil menunjukkan penambahan sari yakon menurunkan kadar gula total secara signifikan p=0.015 dan meningkatkan flavonoid p=0.000. Nilai pH akhir berada pada kisaran aman (2,54–2,62) dan tidak terdapat perbedaan signifikan pada uji organoleptik p>0.05. Umbi yakon mendukung pertumbuhan mikroba selama fermentasi. Formulasi F3 (30%) ditetapkan sebagai perlakuan terbaik karena memiliki pH aman, kadar gula rendah setelah pengenceran, serta tingkat kesukaan panelis tertinggi.

Kata Kunci: kombucha, teh hijau, umbi yakon

Introduction

Kombucha is a fermented beverage made from tea, sugar, and a symbiotic culture. This fermentation process produces various bioactive compounds that provide specific health benefits to the host. During fermentation, the added sugar is broken down by microorganisms, producing acetic, gluconic, and lactic acids, and other metabolites (Tran et al., 2024). Existing studies have shown that kombucha contains bioactive compounds with therapeutic potential, derived from its fermentation process. Kombucha tends to be lower in calories than other fermented beverages. Studies have shown that it can help reduce cholesterol and triglyceride levels, as well as comorbidities related to obesity and diabetes (Phan-Van et al., 2024).

Green tea has significant antioxidant activity, which is largely attributed to its high catechin content. Catechins are polyphenolic compounds that play a key role in the health benefits of green tea. Research shows that green tea has higher antioxidant activity than other types of tea, such as black and oolong tea, which undergo fermentation, reducing their catechin content (Khan & Mukhtar, 2018). Oolong tea has lower antioxidant activity than that of green tea. This is because oolong tea undergoes partial fermentation, resulting in catechin oxidation. Black tea has lower antioxidant activity than green and oolong teas. This is because black tea undergoes complete fermentation.

Yacon tubers have a high water content and natural sweetness derived from fructooligosaccharides compared to other tubers. They are also relatively low in calories and fat, yet rich in phenolic compounds that act as antioxidants. Studies have shown that yacon syrup consumption can improve insulin sensitivity in obese individuals, suggesting potential benefits in managing metabolic conditions. According to Dionísio et al. (2020), explained that consumption of yacon syrup can affect lipid metabolism in healthy subjects (Dionísio et al., 2020)

Kombucha, which is formulated with a blend of green tea and yacon tubers, boasts a diverse nutritional profile. This is due to the combination of nutrients from green tea and the bioactive compounds from the yacon tubers. Green tea contains polyphenolic compounds, particularly catechins, such as epigallocatechin gallate (EGCG). Yacon tubers, rich in fructooligosaccharides (FOS) and inulin, act as natural prebiotics that support the growth of beneficial microbes during fermentation. During kombucha fermentation, the sugar in Yacon is partially converted into organic acids, producing additional bioactive compounds that enhance its health benefits. This combination results in a low-calorie probiotic beverage. It also supports digestive health, helps regulate blood sugar levels, and offers antioxidant and anti-inflammatory effects.

This study differs from previous research on treatment, such as formulations divided into four groups. Previous research used only two treatment groups with two formulations, namely a combination of sugar-kombucha and Yacon-kombucha (Durães et al., 2021). This study enriches the scientific literature on the interactions between tea-based fermentation substrates and natural prebiotic ingredients in the formation of bioactive compounds, such as flavonoids. This study also evaluated the chemical characteristics of honey, including total sugar content, pH, flavonoid content, and organoleptic properties.

The results are expected to have implications for food science and biotechnology, particularly in the development of natural fermentation products with high antioxidant activities. Thus, this study aimed to analyze the effect of adding yakon tuber extract on the chemical and organoleptic characteristics of green tea kombucha.

Methods

This research was a true experimental study using a Completely Randomized Design (CRD). The main ingredients used are green tea (*Camellia sinensis*), granulated sugar, kombucha starter, and yacon tubers (*Smallanthus sonchifolius*). Kombucha production was conducted at the Dietetics and Culinary Laboratory of Universitas Brawijaya in August 2025.

The chemical characteristics of kombucha prepared with green tea and yakon tuber formulations were tested at the Biochemistry Laboratory of Universitas Brawijaya to determine the total sugar content and flavonoid levels. pH testing was carried out at the Nutrient Analysis Laboratory for 2 days during fermentation, and the Organoleptic Laboratory Universitas Brawijaya (organoleptic test). Four treatments of adding yacon tuber extract to green tea kombucha were carried out with a percentage of F0 = 100% green tea water, F1 = 90% green tea water: 10% yacon tuber extract, F2 = 80% green tea water: 20% yacon tuber extract, F3 = 70% green tea water: 30% yacon tuber extract, 50 grams of granulated sugar, and 50 ml of kombucha starter. Each experiment was performed in triplicate. The method for making the product is shown in the image below.

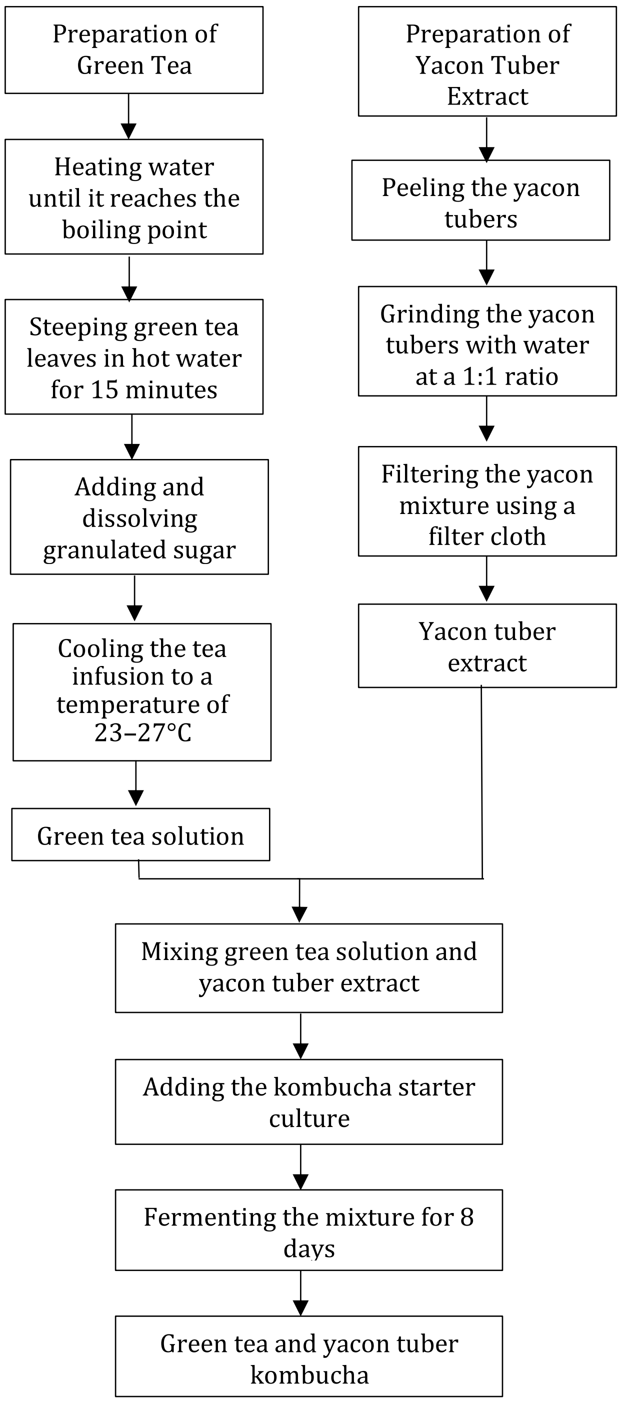

Figure 1. How to make green tea and yacon tuber kombucha

The temperature during fermentation is 23-27 °C, with aerobic fermentation using a kombucha starter mixed into a glass jar. The container was then covered with a porous cloth to allow air exchange and stored in a place protected from direct sunlight. The mixture is then fermented for eight days until optimal, producing a kombucha beverage. The pH levels were measured using a Mettler Toledo pH meter. Measurements were made by turning on and calibrating it for 15-30 minutes before each use. The instrument was calibrated using buffers at pH 4.0, 7.0, and 10.00. For each sample measurement, the instrument electrode was rinsed with distilled water and dried with tissue. After calibration, measurements were continued with the desired sample.

Total sugar content was determined using the 1% 3,5-dinitrosalicylic acid (DNS) method. The DNS solution was prepared from a homogenized mixture of NaOH, sodium potassium tartrate, DNS, and Na_2SO_3. A 1 g sample was hydrolyzed with 50 mL of 4 N HCl at 80 °C for 2 h, cooled, neutralized to pH 7, diluted to 100 mL, and then filtered. The filtrate (1 mL) was reacted with 1 mL of DNS reagent, heated for 10 min, and then measured at 540 nm. A 100–500 ppm glucose standard was used to create a linear regression curve to calculate the sugar content.

The total flavonoid content was analyzed using a spectrophotometric method. A 1 mL kombucha sample was centrifuged to obtain a clear filtrate; 1 mL of the filtrate was then mixed with 1 mL of 95% ethanol, 0.1 mL of 10% $AlCl_3$ solution, and 0.1 mL of 1 M sodium acetate. The mixture was homogenized and allowed to react for 30 min at room temperature. The absorbance was measured using a UV–Vis spectrophotometer at a wavelength of 415 nm. Flavonoid content values were expressed as mg quercetin equivalents (QE) per 100 g of sample based on a quercetin standard curve.

The organoleptic assessment comprised texture/consistency, taste, aroma, and color. Organoleptic testing was conducted on 30 trained panelists. Trained panelists were nutrition science students of the Faculty of Health Sciences, Universitas Brawijaya, who had conducted or were experienced in conducting sensory or organoleptic tests. The trained panelists recorded their product assessments on score sheets. The assessment used in this organoleptic test was a hedonic test. The test method used a scale with one as the lowest score and seven as the highest.

All statistical analyses were performed using the IBM SPSS software (version 25). The data obtained were first tested for normality. The data were analyzed using Analysis of Variance (ANOVA), followed by a post Hoc Test. If the data are not normally distributed, the Kruskal-Wallis or Mann-Whitney test will be used. All statistical tests were performed at a 5% significance level, corresponding to a 95% confidence level. If significant differences were found between treatments, Duncan's Multiple Range Test (DMRT) was used to determine the differences. Testing was performed to determine the best treatment using the Zeleny method.

Ethical approval for this study was granted by the Research Ethics Committee of Universitas Brawijaya, documented in Ethical Clearance No. 00109/UN10.F1723/B/PT/2025.

Result and Discussion

pH is the degree of acidity that is useful for maintaining product safety. The optimal pH is generally between 2.5 and 4.2 (de Miranda et al., 2022). The following pH values were obtained during fermentation:

Table 1. pH changes between times on day 0 and day 8

Formulation	Mean Value on Day 0 (Mean ± SD)	P-Value	Mean Value on Day 8 (Mean ± SD)	P-Value
F0	2.70 ± 0.03	0,16	2.54 ± 0.04	0,14
F1	2.80 ± 0.66		2.67 ± 0.12	
F2	3.22 ± 0.18		2.69 ± 0.06	
F3	3.24 ± 0.10		2.62 ± 0.05	

In this study, after eight days of fermentation, the pH values ranged from 2.54 to 2.62. During fermentation, the pH of kombucha decreased owing to the interactions between yeast and bacteria. Yeast hydrolyzes sucrose into glucose, fructose, and ethanol, whereas acetic acid bacteria (AAB) oxidize ethanol into major organic acids, including acetic, gluconic, and glucuronic acids. This process increases the total acidity and causes a progressive decrease in pH.

In addition, sugar consumption by microorganisms promotes the accumulation of acidic metabolites, further lowering the pH and resulting in a more acidic taste of kombucha (Kuzu et al., 2023; Onsun et al., 2025). Under conditions of increasing acidity, enzymatic and chemical reactions occur that alter the original polyphenolic content of the raw materials. According to Kim et al. (2023), enzymes produced by microbes can hydrolyze complex polyphenols into simpler forms, such as catechin, epicatechin, and free phenolic acids. This results in an increase in the total soluble polyphenol and flavonoid content during the initial phase of fermentation (Kim et al., 2023).

Table 2. Average total sugar content and flavonoid content for each formulation

Formulation	Mean Total Sugar Content (%) (Mean ± SD)	p-value	Mean Flavonoid Content (mg QE/g/100g) (Mean ± SD)	p-value
F0	6.72 ± 0.05	0.015	1.60 ± 0.03	0.000
F1	6.44 ± 0.57		1.66 ± 0.13	
F2	4.66 ± 0.81		1.99 ± 0.15	
F3	6.20 ± 0.14		2.26 ± 0.05	

The Mann–Whitney test showed no significant difference in the total sugar content between F0 and F1 (p = 0.46), F0 and F2 (p = 0.46), F0 and F3 (p = 0.46), F1 and F2 (p = 0.50), F1 and F3 (p = 0.50), and F2 and F3 (p = 0.50). Yacon tubers are rich in carbohydrates, including fructooligosaccharides (FOS) and inulin. The sugar content in yacon tubers is typically lower than the total carbohydrate content. Some analyses indicate that yacon syrup or extract contains a higher percentage of FOS than sugar (Chessum et al., 2023). Yacon FOS is relatively resistant to digestion and is not fully degraded during kombucha fermentation.

This is because the ability of yeast and bacteria to break down FOS depends on the microbial species. Some microbes can utilize FOS, but many remain stable or only partially ferment it during fermentation (Durães et al., 2021). Therefore, adding yacon extract to kombucha can reduce the levels of simple sugars.

In the F2 formulation, using 20% yacon may be sufficient to partially replace simple sugars and significantly reduce the total sugar content without drastically affecting the fermentation process. At a lower yacon concentration of 10%, microbial activity may be reduced owing to limited nutrient availability, resulting in higher residual sugar levels. Conversely, in the F3 formulation, some of the yacon sugars (fructooligosaccharides) may not have been fully hydrolyzed, leading to an increase in the measured total sugar content.

Flavonoids are bioactive compounds derived from tea leaves and serve as the primary raw material for kombucha production. The Post Hoc test results indicated significant differences between F0 and F2 ($p = 0.01$), F0 and F3 ($p = 0.00$), F1 and F2 ($p = 0.02$), and F1 and F3 ($p = 0.00$). No significant differences were observed between F0 and F1 ($p = 0.86$) and between F2 and F3 ($p = 0.05$).

Flavonoids are a group of polyphenols often found in plants that contain free radicals. Flavonoids are a group of polyphenols naturally found in kombucha ingredients, such as green and black tea and other herbs. In one study using green/black tea products, approximately 70.2% of the 127 phenolic compounds identified were flavonoids (Cardoso et al., 2020). The total flavonoid content of kombucha varies depending on the tea substrate, additives, and fermentation conditions. Kombucha made from horchata tea has a much lower flavonoid content of approximately 1.902 ± 0.0455 mg QE/g DW (Mihai et al., 2024). This suggests that the type of tea significantly influences the flavonoid content of kombucha. During kombucha fermentation, flavonoid levels can increase due to the enzymatic activity of microorganisms, particularly β-glucosidase, which breaks down complex polyphenol compounds into simpler, more readily extractable flavonoids.

Flavonoids are found in the tubers, skin, and leaves of yacon. Research has shown that flavonoids in yacon contribute to antioxidant activity that helps ward off free radicals, making yacon a potential functional food. The flavonoid compounds detected in yacon tubers include rutin, quercetin, and kaempferol. The specific content depends on the variety and extraction methods used. Based on the research conducted by Vo et al. (2024). Yacon tubers also contain flavonoids. It was reported that yacon tuber extract produced 7.95 mg RE/g of extract. Green tea is rich in polyphenolic compounds, most of which are flavonoids. Specifically, the flavan-3-ol group is known as catechins. These catechin compounds include epigallocatechin (EGC), epicatechin gallate (ECG), and epigallocatechin gallate (EGCG). Because of its flavonoid content, green tea is often associated with antioxidant, anti-inflammatory, and cell-protective effects against oxidative stress. Several studies have shown that green tea contains flavonoids (Radeva-Ilieva et al., 2025; Sun et al., 2022). In a study using green tea leaf extract from Makassar, the total flavonoid content was reported to be 2.77–3.14 mg QE/g extract (Fawwaz et al., 2022).

Table 3. Median organoleptic quality score of the product

Parameter	Formulation (min - max)				p-value
	F0	F1	F2	F3	
Color	6.00 (3.00 - 7.00)^a	5.00 (3.00 - 7.00)^a	5.00 (3.00 - 7.00)^a	5,00 (3.00 - 7.00)^a	0.355
Aroma	5.00 (2.00 - 7.00)^a	5.00 (2.00 - 7.00)^a	4.00 (2.00 - 7.00)^a	5.00 (2.00 - 7.00)^a	0.348
Consistency	5,50 (3.00 - 7.00)^a	5.00 (3.00 - 7.00)^a	5.00 (3.00 - 7.00)^a	5.00 (1.00 - 7.00)^a	0.614
Taste	5.50 (3.00 - 7.00)^a	5.00 (3.00 - 7.00)^a	5.00 (3.00 - 7.00)^a	5.00 (1.00 - 7.00)^a	0.614

Subscript letter (a) indicates the absence of significant differences

Based on the Kruskal–Wallis test, the obtained values for color (0.36, $p > 0.05$), aroma (0.35, $p > 0.05$), consistency (0.61, $p > 0.05$), and taste (0.61, $p > 0.05$) indicated no significant differences among the treatments.

The data showed that the panelists' assessments of the kombucha color were stable across all formulations. This indicates that the yellow color of the kombucha was generally well received and consistent across all formulation variations, with no significant differences between the treatments. Several panelists reported that the color was attractive, indicating that this visual aspect was sufficient to support the initial product acceptance. However, some panelists found the product color to be less attractive. This indicates that, despite the favorable assessments, the yellow color of kombucha had not yet reached the ideal level of liking according to all panelists' preferences. Sensory analysis of the flower-based kombucha showed that the fermented color received acceptance scores ranging from "slightly like" to "like." (Shanzet et al., 2023). This finding supports the importance of color as an organoleptic parameter.

The panelists' organoleptic test results for aroma parameters showed that each formulation (F0, F1, F2, and F3) received a wide variety of assessments. For some formulations, such as F0 and F2, the percentage of panelists who gave "neutral" and " slightly dislike " ratings was quite high, especially for F2, which had the highest neutral score. This aligns with the panelists' criticism and suggestions that the product's fermentation aroma was still quite strong, which could affect their level of preference. For kombucha made with alternative ingredients, panelists assigned lower aroma scores when the aroma was considered too strong, compared with kombucha that produced a milder aroma (Kilmanoglu et al., 2024). Although the "slightly like" and "like" categories remained present across all formulations, the predominance of “neutral” and "slightly dislike" ratings indicates that some panelists did not fully acceptthe products aroma. This suggests that controlling the fermentation process, such as fermentation duration, microbial culture type, and environmental conditions, is crucial for avoiding off-flavors and enhancing the sensory acceptance of kombucha.

The panelists' organoleptic test results for consistency parameters showed that F1 had a high rating of "slightly like." Meanwhile, F3 had the highest rating in the “neutral” category, with several panelists strongly disliking the consistency of the product. This aligns with the panelists' criticisms and suggestions. F3 appeared cloudier and contained sediment compared to F0. Therefore, product clarity influenced the assessment of the product.

During kombucha fermentation, SCOBY not only produces organic acids, alcohol, and bioactive substances but also forms a cellulose biomass, namely a pellicle or gel layer (biofilm) on the surface of the liquid (Santiago-Santiago et al., 2025). When kombucha is stored or further processed, particles from the SCOBY can be released into the kombucha, leading to sedimentation or cloudiness. In kombucha with non-conventional substrates, additional fiber or cellulose particles from the substrate can increase the potential for sedimentation. The liquid may become denser and slightly cloudy. This can affect the consumer perception of texture.

Based on the organoleptic evaluation by the panelists for the taste parameter, most formulations were rated as neutral, slightly liked, and liked. Formulation F3 showed a tendency toward more positive ratings than F0, with several panelists noting that F3 had a fresher taste. However, some panelists reported that the yacon tuber flavor was not sufficiently pronounced. This observation is consistent with the neutral ratings and small proportion of responses in the “dislike” category. Overall, although F3 was perceived as fresher and more preferred than F0, the intensity of the yacon flavor still needs to be enhanced to make its taste characteristics more distinct and uniformly acceptable to the panelists.

Based on the above explanations and the tests carried out to determine the best treatment, the F3 treatment was selected. This is assessed based on several factors, including pH, flavonoid and sugar content, and panelists' preference levels. Although the total sugar content of F3 was not the best treatment, after comparing it with other parameters, it showed the best results.

Increasing acid concentration and microbial activity during fermentation can lower the pH and alter the solubility of dissolved solids. This effect often results in a sharper taste and stimulates mucous sensations in the mouth if the acidity is sufficiently high. The sour taste of kombucha is a natural result of microbial activity, particularly that of acetic acid and lactic acid bacteria, which convert sugars into organic acids during fermentation. The concentration of total acids and acidic compounds decreases significantly with increasing beverage pH, whereas acidity (acid titration) increases with fermentation (Essiedu et al., 2024). Acetic acid is often the dominant acid, which gives kombucha its sharp taste (Wang et al., 2023). Kombucha with higher acidity generally tastes more sour, and this acidity level is greatly influenced by fermentation variables, such as duration, temperature, and sugar composition (Cohen et al., 2023).

The research that aligns with this study concerns organoleptic results that show no significant differences in color, aroma, taste, and acceptance globally, likely due to the participants not being used to consuming kombucha or yakon (Durães et al., 2021). The similarities between the panelists used in this study and those in the study were that both groups had never consumed kombucha or yakon tubers before.

Kombucha drinks with the addition of yakon tubers can be developed into a drink suitable for clinical testing, as they contain flavonoids that are better antioxidants than those without yakon tubers.Acknowledgments References These findings could serve as a basis for developing natural prebiotic-based kombucha products with a relatively safe pH for consumption by humans.

The advantage of this study is that it combines a green tea formula with yacon tubers using several formulations that differ from those in previous research. In addition, research on the combination of green tea and yacon tuber is still limited. The limitation of this study is that the repetition is carried out three times, so it is still very limited for tests related to fermentation, does not measure the stability of the product during storage, does not measure the content of the raw materials used, and does not measure clinical parameters or physiological effects. Hence, it is still impossible to provide claims for functional foods that address a particular medical condition.

Conclusion

The addition of yacon tuber extract to green tea kombucha affected the chemical characteristics of the product, particularly its total sugar and flavonoid content. The formula with 30% yacon extract (F3) showed optimal results, with a low total sugar content and the highest flavonoid content when diluted, without significantly affecting organoleptic acceptability. The resulting kombucha had a safe pH for consumption and contained bioactive compounds with potential antioxidant properties.

Future research should monitor humidity during fermentation to optimize fermentation, using additional ingredients that are not easily damaged or oxidized in kombucha, testing the composition of raw materials to enrich the results and discussions, and conducting microbiological analyses of kombucha starters and fermentation results.

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