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Original Article

Development and Evaluation of Kiwi-Based Kombucha as a Functional Beverage Alternative to Carbonated Soft Drinks

Wafa Fatima[1], Sara Sarbuland[1], Malaika Irshad[1], Zainab Masood[2], Maida Mushtaq[3]

[1] School of Health Sciences, University of Management and Technology, Lahore, Pakistan
[2] Lecturer, Nutrition Science Department, School of Health Sciences, University of Management and Technology, Lahore, Pakistan
[3] Lecturer, Physical Therapy and Rehabilitation, School of Health Sciences, University of Management and Technology, Lahore, Pakistan

***Corresponding author: Maida Mushtaq, maida.mushtaq@umt.edu.pk**

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ABSTRACT

Background: Sugar-sweetened carbonated beverages are associated with poor nutritional quality and excess sugar intake, creating interest in fermented functional beverages with improved sensory and biochemical characteristics. Kombucha is a fermented tea beverage containing organic acids and antioxidant-related compounds, while kiwi fruit may contribute vitamin C, organic acids, and polyphenols. Objective: This study aimed to develop kiwi-based kombucha formulations and evaluate their physicochemical changes, antioxidant-related properties, alcohol formation, and sensory acceptability. Methods: An experimental food and nutrition study was conducted using kiwi-enriched kombucha formulations prepared with grapes and either honey or ginger. Fermentation was monitored using pH, total phenolic content, total flavonoid content, FRAP antioxidant activity, DPPH radical scavenging activity, and alcohol content. Sensory evaluation was performed among 25–30 adult volunteers using a 9-point hedonic scale assessing flavour, texture, aroma, appearance, and overall acceptability. Data were analyzed using IBM SPSS Statistics version 27. Results: The honey-based formulation showed higher sensory scores than the ginger-based formulation for flavour (6.84 ± 1.34 vs 5.76 ± 1.27; p = 0.005), texture (6.80 ± 1.41 vs 5.80 ± 1.55; p = 0.021), and overall acceptability (7.64 ± 1.19 vs 6.64 ± 1.82; p = 0.027). pH decreased from approximately 4.2 at baseline to 3.1–3.5 by Day 14. Alcohol peaked at Day 7 in Honey Kiwi Kombucha (3.50 ± 0.50%) and Ginger Kiwi Kombucha (3.25 ± 0.50%). Conclusion: Honey-based kiwi kombucha demonstrated better sensory acceptability than ginger-based formulation, while fermentation produced progressive acidification and measurable alcohol formation. Further standardized testing, complete biochemical reporting, and direct comparison with commercial soft drinks are needed. Keywords: Kombucha, kiwi, functional beverage, fermentation, antioxidant activity, sensory evaluation

EDITORIAL INFORMATION

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INTRODUCTION

Sugar-sweetened carbonated beverages remain widely consumed despite their limited nutritional value and their association with excess sugar intake, poor dietary quality, weight gain, dental health concerns, and adverse metabolic outcomes. Systematic evidence has linked frequent soft-drink intake with unfavorable nutrition and health indicators, while high intake of fructose-containing sugars has also been implicated in pathways related to hepatic de novo lipogenesis and metabolic dysfunction (1,2). These concerns have increased interest in beverage reformulation and substitution strategies that reduce

reliance on conventional carbonated soft drinks. However, an acceptable substitute must not only be nutritionally preferable but also palatable, affordable, and compatible with consumer preferences for natural and clean-label products. Contemporary clean-label trends indicate that consumers increasingly favor products made with recognizable ingredients, minimal artificial additives, and transparent functional benefits, making fruit-enriched fermented beverages a relevant area for functional food development (3).

Kombucha is a fermented tea beverage produced through the activity of a symbiotic culture of bacteria and yeast. During fermentation, yeasts metabolize sugars into ethanol and carbon dioxide, while acetic acid bacteria convert ethanol and other substrates into organic acids that contribute to the beverage's acidity, flavor profile, and microbial stability. The composition of kombucha is influenced by tea substrate, sugar source, fermentation duration, microbial ecology, oxygen exposure, and secondary enrichment ingredients (4,5). Previous reviews and fermentation studies show that kombucha contains organic acids, phenolic compounds, microbial metabolites, and volatile compounds that vary dynamically across fermentation, although these biochemical properties should be interpreted as product characteristics rather than direct clinical evidence of health benefit unless tested in human intervention studies (4–6). Controlled monitoring of pH, alcohol content, antioxidant indices, and sensory characteristics is therefore essential when developing kombucha as a functional beverage.

Fruit enrichment during secondary fermentation can improve both the biochemical profile and consumer acceptability of kombucha. Secondary fermentation with fruit may contribute natural sugars, organic acids, vitamins, pigments, aroma compounds, and polyphenols, while microbial activity may alter the extractability and stability of bioactive constituents (7). Studies on fruit-infused kombucha and fermented beverages suggest that fruit addition can influence antioxidant capacity, acidity, aroma development, and palatability, although the direction and magnitude of these effects depend on the type of fruit, fermentation duration, and formulation conditions (7–9). Sensory acceptability is particularly important because the naturally acidic and sometimes vinegary character of kombucha may limit consumer preference if not balanced by fruit sweetness, aroma, or mouthfeel-enhancing ingredients (8).

Kiwi fruit is a suitable candidate for kombucha enrichment because it contains vitamin C, organic acids, dietary fiber, minerals, and polyphenolic compounds. It also contains actinidin, a proteolytic enzyme that contributes to the distinctive functional profile of kiwifruit (10,11). Kiwifruit pectin and related dietary fiber components may also provide prebiotic relevance, although such effects require direct microbiological or gastrointestinal evaluation before being claimed for a final beverage product (12). Grapes may further contribute polyphenolic compounds, while honey can influence sweetness, mouthfeel, and fermentable substrate availability, and ginger can contribute pungent sensory notes and bioactive phytochemicals (13–15). Because these ingredients can affect both fermentation behavior and sensory response, formulation-level comparison is needed rather than assuming that all fruit-enriched kombucha preparations perform similarly.

Despite growing interest in kombucha and fruit-based functional beverages, limited experimental work has specifically evaluated kiwi-enriched kombucha using combined physicochemical, antioxidant, alcohol, and sensory outcomes. Much of the available evidence addresses plain tea kombucha, general kombucha microbiology, or other fruit-enriched fermented beverages, while local evidence from nutritional sciences settings remains limited. In addition, although kiwi-based kombucha may be positioned as a potential alternative to sugar-sweetened carbonated beverages, such a claim requires cautious interpretation unless direct comparison with commercial soft drinks is performed. The present study therefore focused on formulation development and preliminary laboratory and sensory evaluation rather than direct clinical or market-level substitution.

This study aimed to develop kiwi-based kombucha formulations and evaluate their physicochemical changes, antioxidant-related properties, alcohol formation, and sensory acceptability. Specifically, the study assessed changes in pH, total phenolic content, total flavonoid content, ferric reducing antioxidant power, DPPH radical scavenging activity, and alcohol content during fermentation, and compared the sensory acceptability of honey-based and ginger-based kiwi kombucha formulations using a 9-point

hedonic scale. The central research question was whether kiwi-enriched kombucha formulations demonstrate favorable fermentation characteristics and consumer acceptability that support further development as functional beverage candidates.

MATERIALS AND METHODS

This study was conducted as an experimental food and nutrition research study involving formulation development, fermentation monitoring, laboratory analysis, and sensory evaluation of kiwi-based kombucha beverages. The experimental component assessed physicochemical and antioxidant-related changes during fermentation, while the sensory component compared consumer acceptability of two kiwi-enriched formulations. The study was carried out over six months after synopsis approval in the Department of Nutrition and Dietetics, School of Health Sciences, University of Management and Technology, Lahore, Pakistan.

Kombucha was prepared using sweetened tea inoculated with a symbiotic culture of bacteria and yeast. The fermentation approach was based on established kombucha preparation principles in which yeasts and acetic acid bacteria metabolize available sugars and generate organic acids, ethanol, carbon dioxide, and other fermentation metabolites (4–6). After primary fermentation, secondary fruit enrichment was performed using fresh kiwi and grapes with either honey or ginger, producing two main formulations: Honey Kiwi Kombucha and Ginger Kiwi Kombucha. Plain kombucha was retained as a reference formulation for selected laboratory comparisons where applicable. The use of fruit enrichment during secondary fermentation was based on prior evidence that fruit addition can modify antioxidant-related compounds, acidity, volatile profile, and sensory characteristics of kombucha (7,8).

Fermentation was monitored up to Day 14. Laboratory measurements were taken at predefined time points according to the parameter being assessed. pH and antioxidant-related outcomes were evaluated across the fermentation period to characterize acidification and changes in bioactive indices. Alcohol content was measured at Day 0, Day 1, Day 7, and Day 14 to document ethanol formation during fermentation, because ethanol production is an expected intermediate outcome of yeast metabolism in kombucha and may vary with formulation and fermentation duration (5,6). Laboratory analyses were performed in triplicate where applicable to improve analytical reliability.

Healthy adult participants were recruited through non-probability convenience sampling for sensory evaluation. Eligible participants were adults aged 18–60 years who were willing to provide written informed consent and participate in beverage tasting. Participants were excluded if they were pregnant or breastfeeding, had known allergy or intolerance to kiwi, grapes, honey, ginger, tea-based fermented beverages, or related ingredients, had gastrointestinal disorders or immunocompromising conditions, were currently taking antibiotics or probiotic supplements, or were unwilling to complete the study procedure. The sensory panel consisted of approximately 25–30 university students and academic or non-academic staff members from an urban institutional setting. Because recruitment was based on convenience sampling, the findings were interpreted as preliminary product-level acceptability data and not as nationally generalizable consumer preference estimates.

Laboratory analysis included physicochemical and antioxidant assessment of the prepared kombucha samples. pH was measured using a calibrated digital pH meter to determine acidity changes during fermentation. Total phenolic content was determined using the Folin–Ciocalteu method and expressed as gallic acid equivalents per 100 mL. Total flavonoid content was determined using the aluminum chloride colorimetric method and expressed as quercetin equivalents per 100 mL. Antioxidant activity was assessed using DPPH radical scavenging activity and ferric reducing antioxidant power assays, which are commonly used in food and beverage studies to estimate in vitro radical-scavenging and reducing capacity (7,9). For the DPPH assay, sample extract was mixed with DPPH solution, incubated in the dark, and absorbance was measured at 517 nm using a UV–Vis spectrophotometer. For total phenolic content, the sample was reacted with Folin–Ciocalteu reagent followed by sodium carbonate solution, incubated, and absorbance was measured at 765 nm. For total flavonoid content, sample extract was mixed with aluminum chloride reagent, incubated at room temperature, and absorbance was measured at 415 nm.

Alcohol content was measured during fermentation to assess ethanol formation in Honey Kiwi Kombucha and Ginger Kiwi Kombucha.

Sensory evaluation was conducted after completion of fermentation when the beverages had reached acceptable acidity and product stability. Participants received coded samples of the kiwi-based kombucha formulations in a controlled classroom or laboratory setting to minimize environmental bias. Samples were served in standardized volumes and at comparable serving temperature, and participants were instructed to evaluate each sample independently. Water was provided for palate cleansing where required. A structured self-administered sensory evaluation questionnaire was used to assess appearance or color, aroma, taste or flavour, texture or mouthfeel, sweetness level, and overall acceptability. Each attribute was rated using a 9-point hedonic scale, where 1 indicated "dislike extremely" and 9 indicated "like extremely." The hedonic scale approach was selected because it is widely used in sensory evaluation of food and beverage acceptability and has been applied in previous kombucha sensory studies (8).

The main independent variables were beverage formulation and fermentation time. Beverage formulation included Honey Kiwi Kombucha, Ginger Kiwi Kombucha, and plain kombucha where relevant to laboratory comparisons. Fermentation time was treated as a repeated experimental condition for laboratory measurements. The primary laboratory outcomes were pH, total phenolic content, total flavonoid content, DPPH radical scavenging activity, FRAP antioxidant activity, and alcohol percentage. The primary sensory outcomes were hedonic scores for flavour, texture, aroma, appearance, sweetness, and overall acceptability. Kiwi-based kombucha was operationally defined as a fermented tea beverage prepared using SCOBY, sweetened tea, and fresh kiwi fruit during secondary fermentation. Sensory acceptability was operationally defined as participant preference measured using the 9-point hedonic scale across the specified sensory attributes.

Several steps were used to reduce bias and improve data quality. Sensory samples were coded before serving to reduce expectation bias, and responses were recorded immediately after tasting to minimize recall bias. Eligibility screening was used to reduce safety risks related to allergy, intolerance, pregnancy, immunocompromising conditions, and recent antibiotic or probiotic use. Laboratory analyses were performed in triplicate where applicable, and equipment calibration and standardized assay procedures were followed to improve measurement consistency. Data were entered into IBM SPSS Statistics version 27 for analysis, and incomplete sensory responses were excluded from attribute-specific analysis when the relevant item was missing.

Descriptive statistics were used to summarize laboratory and sensory outcomes. Continuous variables were reported as mean ± standard deviation where appropriate. Sensory scores for the two kiwi kombucha formulations were compared attribute-wise. Because the same sensory participants were expected to evaluate both formulations, paired-samples analysis was considered the appropriate primary approach for comparing formulation-level sensory scores. Where assumptions of normality were not satisfied, a non-parametric paired alternative was considered. For laboratory outcomes measured across formulation and fermentation time, repeated-measure or factorial analysis was considered where the data structure was complete; where exact values or assumptions were insufficient, descriptive trend analysis was used to avoid unsupported inferential claims. Statistical significance was assessed at $p < 0.05$.

Ethical principles for human participant research were followed throughout the sensory evaluation. Written informed consent was obtained before participation. Participants were informed about the purpose of the study, voluntary nature of participation, right to withdraw, confidentiality of responses, and potential allergy-related risks. No personal identifiers were used in the analysis or reporting of sensory data. Participants with known allergies or contraindications to the beverage ingredients were excluded from tasting. All collected data were kept confidential and used only for academic and research purposes.

RESULTS

A total of 25–30 adult participants completed the sensory evaluation of two kiwi-based kombucha formulations. Drink 1 consisted of kiwi, grapes, and honey, whereas Drink 2 consisted of kiwi, grapes, and

ginger. Sensory attributes were evaluated using a 9-point hedonic scale, with higher scores indicating greater preference. Laboratory analyses were performed to evaluate changes in pH, total phenolic content, total flavonoid content, FRAP antioxidant activity, DPPH radical scavenging activity, and alcohol content during fermentation.

Table 1. Sensory Evaluation Scores of Kiwi-Based Kombucha Formulations

Sensory Attribute	Drink 1 Mean ± SD	Drink 2 Mean ± SD	t	p-value
Flavour	6.84 ± 1.34	5.76 ± 1.27	2.92	0.005
Texture	6.80 ± 1.41	5.80 ± 1.55	2.38	0.021
Aroma	6.46 ± 2.30	5.84 ± 2.44	0.91	0.366
Appearance	7.08 ± 1.63	6.52 ± 1.61	1.22	0.228
Overall Acceptability	7.64 ± 1.19	6.64 ± 1.82	2.30	0.027

SD, standard deviation; Drink 1, kiwi + grapes + honey kombucha; Drink 2, kiwi + grapes + ginger kombucha.

Drink 1 demonstrated higher mean sensory scores than Drink 2 across all evaluated attributes. The largest difference was observed for flavour, where Drink 1 scored 6.84 ± 1.34 compared with 5.76 ± 1.27 for Drink 2, with a reported t-value of 2.92 and p-value of 0.005. Texture was also rated higher for Drink 1, with a mean score of 6.80 ± 1.41 compared with 5.80 ± 1.55 for Drink 2, with a reported t-value of 2.38 and p-value of 0.021. Overall acceptability favored Drink 1, with a mean score of 7.64 ± 1.19 compared with 6.64 ± 1.82 for Drink 2, with a reported t-value of 2.30 and p-value of 0.027. Aroma and appearance scores were numerically higher for Drink 1; however, the differences were not statistically significant, with p-values of 0.366 and 0.228, respectively.

Table 2. ANOVA Results for Sensory Attributes of Kiwi-Based Kombucha Formulations

Sensory Attribute	F	p-value
Flavour	8.53	0.005
Texture	5.67	0.021
Aroma	0.82	0.366
Appearance	1.47	0.228
Overall Acceptability	5.31	0.027

The ANOVA results showed statistically significant differences between the formulations for flavour, texture, and overall acceptability. Flavour showed an F-value of 8.53 with a p-value of 0.005, while texture showed an F-value of 5.67 with a p-value of 0.021. Overall acceptability also differed significantly between the two formulations, with an F-value of 5.31 and p-value of 0.027. Aroma and appearance did not show statistically significant differences between the two beverages, with p-values of 0.366 and 0.228, respectively.

Table 3. Alcohol Content of Kiwi-Based Kombucha Formulations During Fermentation

Beverage Formulation	Day	Alcohol % Mean ± SD
Honey Kiwi Kombucha	0	0.00 ± 0.00
Honey Kiwi Kombucha	1	0.40 ± 0.00
Honey Kiwi Kombucha	7	3.50 ± 0.50
Honey Kiwi Kombucha	14	3.00 ± 0.00
Ginger Kiwi Kombucha	0	0.00 ± 0.00
Ginger Kiwi Kombucha	1	0.30 ± 0.00
Ginger Kiwi Kombucha	7	3.25 ± 0.50
Ginger Kiwi Kombucha	14	2.00 ± 0.00

SD, standard deviation.

Alcohol content increased in both formulations during early fermentation. Honey Kiwi Kombucha increased from 0.00 ± 0.00% at Day 0 to 0.40 ± 0.00% at Day 1 and reached 3.50 ± 0.50% at Day 7, followed by a decrease to 3.00 ± 0.00% at Day 14. Ginger Kiwi Kombucha increased from 0.00 ± 0.00% at Day 0 to 0.30 ± 0.00% at Day 1 and reached 3.25 ± 0.50% at Day 7, followed by a decrease to 2.00 ± 0.00% at Day 14. Honey Kiwi Kombucha showed numerically higher alcohol content than Ginger Kiwi Kombucha at all post-baseline time points.

The pH decreased progressively across Ginger Kiwi Kombucha, Honey Kiwi Kombucha, and plain kombucha during fermentation. The pH declined from approximately 4.2 at Day 0 to approximately 3.1–3.5

by Day 14, indicating increasing acidity as fermentation progressed. This reduction in pH reflects acid production during fermentation and supports successful acidification of the kombucha samples.

Table 4. pH Changes During Fermentation

Parameter	Day 0	Day 14
pH range across samples	4.2	3.1–3.5

Total phenolic content, total flavonoid content, FRAP antioxidant activity, and DPPH radical scavenging activity varied across formulations and fermentation time. Plain kombucha generally showed the highest total phenolic content, whereas Ginger Kiwi Kombucha showed the lowest. Honey Kiwi Kombucha showed the highest total flavonoid content at the start of fermentation and generally maintained higher levels than the other samples, although all formulations showed a declining trend in flavonoid concentration from Day 0 to Day 14. FRAP antioxidant activity varied during fermentation, with Honey Kiwi Kombucha generally showing higher activity than Ginger Kiwi Kombucha. DPPH radical scavenging activity also varied by formulation and fermentation duration, with plain kombucha and Honey Kiwi Kombucha generally showing stronger activity than Ginger Kiwi Kombucha.

Overall, the sensory findings indicate that the honey-based kiwi kombucha formulation had higher acceptability than the ginger-based formulation, particularly for flavour, texture, and overall acceptability. Fermentation was associated with progressive pH reduction and measurable alcohol formation, with alcohol content peaking at Day 7 in both kiwi-based formulations. The antioxidant-related findings showed formulation-dependent and time-dependent variation in phenolic content, flavonoid content, FRAP activity, and DPPH activity, suggesting that both ingredient composition and fermentation duration influenced the functional characteristics of the beverages.

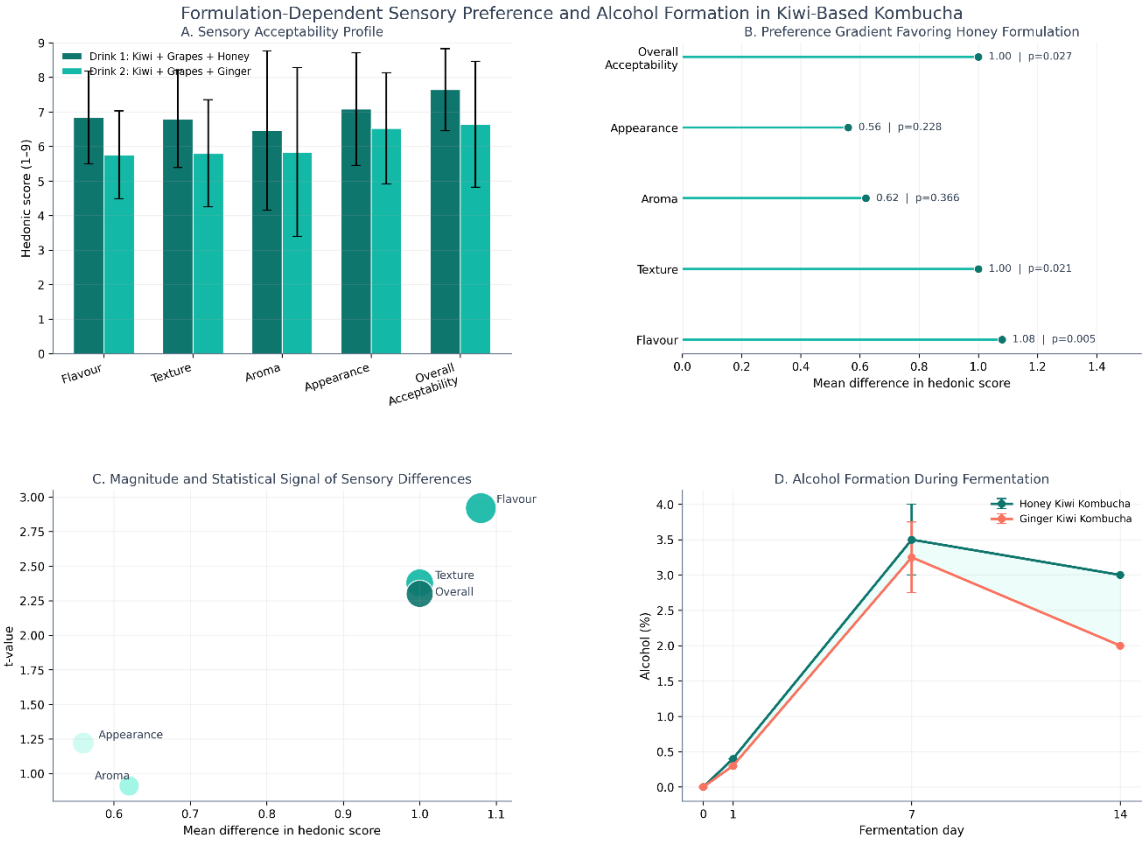

Figure 1 Formulation-Dependent Sensory Preference and Alcohol Formation in Kiwi-Based Kombucha

The panelled figure shows that the honey-based kiwi kombucha formulation consistently achieved higher sensory scores than the ginger-based formulation across all evaluated attributes, with the largest mean difference observed for flavour (1.08 points; p = 0.005), followed by texture (1.00 point; p = 0.021) and overall acceptability (1.00 point; p = 0.027). Aroma and appearance showed smaller differences of 0.62 and 0.56 points, respectively, with p-values above 0.05. Alcohol formation increased sharply in both

formulations during fermentation, reaching peak values at Day 7 in Honey Kiwi Kombucha (3.50 ± 0.50%) and Ginger Kiwi Kombucha (3.25 ± 0.50%), followed by a decline at Day 14 to 3.00 ± 0.00% and 2.00 ± 0.00%, respectively. Overall, the figure highlights two key formulation-level findings: honey improved sensory preference, while both formulations produced measurable alcohol concentrations that require safety and labeling consideration.

DISCUSSION

The present study developed and evaluated kiwi-based kombucha formulations using sensory assessment and selected laboratory indicators of fermentation behavior, antioxidant-related activity, acidity, and alcohol formation. The main finding was that the honey-based formulation, consisting of kiwi, grapes, and honey, showed higher sensory acceptability than the ginger-based formulation across all assessed attributes. The strongest differences were observed for flavour, texture, and overall acceptability, where the honey-based formulation achieved higher mean scores than the ginger-based formulation. Flavour was rated 6.84 ± 1.34 in the honey formulation compared with 5.76 ± 1.27 in the ginger formulation, while texture was rated 6.80 ± 1.41 compared with 5.80 ± 1.55, and overall acceptability was rated 7.64 ± 1.19 compared with 6.64 ± 1.82. These differences suggest that honey may have improved the balance between sweetness, acidity, and mouthfeel, thereby increasing preference for the fermented beverage. Previous sensory research on beverages indicates that sweetness can moderate sourness and pungency, while pungent ingredients may reduce acceptability if their intensity exceeds consumer tolerance (16). This interpretation is consistent with the present findings, where the ginger-based formulation remained acceptable but received lower flavour, texture, and overall acceptability scores.

The superior acceptability of the honey-based formulation is also biologically and technologically plausible. Honey contributes fermentable sugars, aroma compounds, viscosity, and natural sweetness, all of which can influence fermentation behavior and sensory perception. Prior literature describes honey as a complex natural ingredient containing carbohydrates and minor bioactive constituents, and its use in beverage formulations may improve palatability when balanced appropriately (17). In contrast, ginger contributes pungent phenolic compounds, including gingerols and related constituents, which may enhance the functional identity of a beverage but can also produce a sharper taste and aroma profile (18). Fermentation may further modify ginger-derived compounds and their sensory expression, which could explain why the ginger formulation was less preferred despite remaining within the acceptable range of the hedonic scale (19). Therefore, the present findings support the need for careful optimization of ginger concentration rather than excluding ginger as a formulation ingredient.

The role of fruit enrichment should also be considered in interpreting the sensory and antioxidant-related findings. Kiwi was selected because of its vitamin C, organic acids, dietary fiber, minerals, phenolic compounds, and actinidin content, while grapes may contribute additional polyphenols and aroma-related constituents. Grape polyphenols are well recognized for their antioxidant activity, and their inclusion in both formulations may have contributed to the overall bioactive potential of the beverages (20). Similarly, kiwi-derived pectin and fiber may have functional relevance in fermented beverage matrices, although the present study did not directly evaluate prebiotic activity, microbial survival, or gastrointestinal outcomes (21). These ingredient-level properties support the rationale for kiwi-grape enrichment, but they should be interpreted as formulation rationale rather than proof of clinical benefit.

The observed reduction in pH during fermentation confirms successful acidification of the kombucha matrix. The manuscript reports that pH decreased from approximately 4.2 at baseline to approximately 3.1–3.5 by Day 14 across the tested samples. This pattern is consistent with kombucha fermentation, where yeasts and acetic acid bacteria metabolize sugars and generate ethanol, carbon dioxide, acetic acid, gluconic acid, and other organic acids. Acetic acid bacteria are central to kombucha fermentation and contribute to acidification, sensory sharpness, and microbial stability of the final beverage (22). Studies on kombucha microbial ecology further show that fermentation conditions, substrate type, oxygen availability, and microbial community structure influence the final acid and volatile compound profile (23). In the present study, the decrease in pH supports fermentation progression and likely contributed to

preservation; however, excessive acidification may reduce palatability, making fermentation duration and refrigerated storage important formulation-control points.

The antioxidant-related findings indicate dynamic formulation- and time-dependent changes rather than a uniform increase in all antioxidant markers. The manuscript describes plain kombucha as generally having the highest total phenolic content, Ginger Kiwi Kombucha as having the lowest phenolic content, and Honey Kiwi Kombucha as showing comparatively higher flavonoid content at the start of fermentation. It also reports that flavonoid concentration generally declined from Day 0 to Day 14, while FRAP and DPPH activities varied across formulation and fermentation duration. This pattern is plausible because fermentation can release bound phenolics, transform existing compounds, degrade unstable phytochemicals, or alter antioxidant assay responses depending on substrate composition and fermentation conditions. Prior work on fruit-enriched kombucha has similarly shown that secondary fermentation can modify bioactive compound availability and antioxidant capacity, but the response varies by fruit type and process conditions (7). Therefore, the current findings should be described as antioxidant variation during fermentation rather than a simple increase in antioxidant activity.

The difference between FRAP and DPPH trends also requires cautious interpretation. FRAP reflects reducing capacity, whereas DPPH estimates radical-scavenging activity; therefore, the two assays may not change identically during fermentation. Ginger and fruit polyphenols may interact differently with these assays depending on compound stability, oxidation state, and fermentation-related transformation (24). However, because the manuscript does not provide complete numerical tables for total phenolic content, total flavonoid content, FRAP, and DPPH, the antioxidant results should be interpreted as preliminary. The final manuscript should include formulation-specific mean ± standard deviation values at each fermentation time point, with appropriate units and statistical comparisons, before making strong claims regarding antioxidant superiority.

Alcohol formation was a key safety-relevant finding. Alcohol content increased in both formulations during early fermentation and peaked at Day 7, reaching 3.50 ± 0.50% in Honey Kiwi Kombucha and 3.25 ± 0.50% in Ginger Kiwi Kombucha, before declining to 3.00 ± 0.00% and 2.00 ± 0.00%, respectively, by Day 14. This pattern is consistent with yeast-driven ethanol production followed by partial oxidation of ethanol by acetic acid bacteria during kombucha fermentation. Previous fermentation studies have shown that ethanol formation and conversion are influenced by yeast activity, acetic acid bacteria, sugar availability, oxygen exposure, and fermentation duration (6,22). The alcohol values reported in this study are not negligible and should be addressed directly in product development, labeling, and consumer safety considerations. If kiwi-based kombucha is positioned as an alternative to carbonated soft drinks, alcohol control becomes essential because such levels may affect suitability for children, pregnant women, individuals avoiding alcohol, and consumers with religious or medical restrictions.

The present study contributes useful preliminary evidence from a local nutrition and food-science context by evaluating sensory acceptability alongside fermentation-related biochemical outcomes. The findings support the feasibility of developing a palatable kiwi-based kombucha beverage, especially with honey as a balancing ingredient. However, the findings should not be interpreted as evidence that kiwi kombucha is clinically superior to carbonated soft drinks, because the study did not directly compare the developed formulations with commercial soft drinks and did not evaluate clinical outcomes such as glycemic response, lipid profile, digestive symptoms, body weight, or metabolic markers. The study instead supports a more cautious conclusion: kiwi-based kombucha, particularly the honey-enriched formulation, demonstrated favorable preliminary sensory characteristics and measurable fermentation-related biochemical changes that justify further formulation refinement and controlled comparative testing.

The study has several limitations. The sensory evaluation included only approximately 25–30 participants recruited through convenience sampling from a single university setting, which limits generalizability. The exact number of participants should be reported consistently across the Methods, Results, and abstract. The same participants appear to have evaluated both formulations; therefore, paired analysis would be more appropriate than independent-samples testing unless the study design confirms separate groups.

The reported ANOVA table also requires clarification because a true two-way ANOVA should specify two independent factors, degrees of freedom, mean square values, and interaction effects. In addition, the study did not report full numerical biochemical data for pH, total phenolic content, total flavonoid content, FRAP, and DPPH across all formulations and time points, limiting statistical interpretation. Important product-quality variables such as residual sugar, total soluble solids, titratable acidity, microbial count, organic acid profile, vitamin C content, shelf-life stability, and refrigerated storage behavior were also not fully reported.

Future research should standardize and fully report tea concentration, sugar concentration, SCOBY quantity, kiwi-to-liquid ratio, grape quantity, honey and ginger levels, fermentation temperature, vessel conditions, oxygen exposure, and storage protocol. Larger sensory studies should use blinded sample coding, randomized serving order, broader demographic representation, and direct comparison with commonly consumed commercial beverages. Laboratory evaluation should include microbial enumeration, residual sugar, titratable acidity, vitamin C, organic acid profile, and alcohol stability under refrigerated storage. Further work may also evaluate whether kiwi fiber, grape polyphenols, honey constituents, or ginger-derived compounds contribute meaningfully to product stability or bioactive potential, but such claims should remain formulation-based unless tested in biological or clinical models. Overall, this study indicates that honey-based kiwi kombucha may offer better sensory acceptability than ginger-based kiwi kombucha, while also demonstrating fermentation-associated acidification, antioxidant variation, and alcohol production that require careful control before product development or broader health-oriented positioning.

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