

Full Length Research Paper

Physico-chemical, sensory, and shelf-life properties of kombucha made with yacon syrup and purple tea

Dinah Ochami^{1*}, Richard Koskei² and Monica Mburu²

¹Food Science and Nutrition Department, Karatina University, Karatina, Kenya.

²Institute of Food Bio Resources Technology, Dedan Kimathi University of Technology, Nyeri, Kenya.

Received 4 August, 2025; Accepted 14 November, 2025

Kombucha is a fermented beverage recognized for its probiotic and antioxidant benefits, yet its formulation with regionally sourced ingredients such as yacon syrup (*Smallanthus sonchifolius*) and purple tea (*Camellia sinensis* var. *assamica*) remains limited. Yacon tubers provide fructooligosaccharides (FOS) and prebiotic fibers that enhance microbial growth, while purple tea contributes to anthocyanins that complement kombucha's tangy profile. This study evaluated physicochemical, mineral, sensory, and shelf-life properties of kombucha prepared with varying ratios of purple tea and yacon syrup. Four treatments were developed: A (control, 100% purple tea + 5% sugar), B (95% purple tea + 5% yacon syrup), C (90% purple tea + 10% yacon syrup), and D (80% purple tea + 15% yacon syrup), each in triplicate. Analyses followed AOAC methods for pH, titratable acidity, soluble solids, and alcohol content; antioxidant activity was assessed using the DPPH radical scavenging assay (59–79% inhibition), polyphenols by the Folin-Ciocalteu method, and minerals via atomic absorption spectrometry. Sensory evaluation employed a 5-point hedonic scale. Results showed significant differences ($p < 0.05$) across treatments: pH ranged 4.1–4.7, acidity 0.46–0.59%, soluble solids 6.3–8.3°Bx, and alcohol 0.5–1.2%. Antioxidant, polyphenol, and mineral levels increased with yacon concentration, with calcium, magnesium, zinc, and iron highest in yacon-rich samples. Sensory scores were superior in yacon formulations, particularly Treatment C. Shelf-life testing indicated refrigerated storage (4°C) maintained stability better than ambient (28°C). Purple tea-yacon kombucha demonstrated improved nutrition and sensory appeal, underscoring its potential as a functional beverage.

Key words: Polyphenols, fermentation, probiotics, prebiotics, antioxidant, functional beverage, minerals.

INTRODUCTION

Kombucha, a fermented beverage traditionally made from *Camellia sinensis* (black tea) leaves and a Symbiotic Culture of Bacteria and Yeast (SCOBY), has garnered global attention for its distinctive sweet-sour flavor and

health-enhancing properties (Barros et al., 2024). Its popularity stems from bioactive compounds formed through microbial fermentation, including antioxidants, probiotics, and anti-inflammatory agents (Laureys et al.,

*Corresponding author. E-mail: dinahochami@gmail.com.

Author(s) agree that this article remain permanently open access under the terms of the [Creative Commons Attribution License 4.0 International License](https://creativecommons.org/licenses/by/4.0/)

2020). Kombucha is known for its health benefits, including the contribution of bioactive compounds and probiotic properties (Zhang et al., 2019; Romualdo et al., 2024). The benefits of antioxidants have been associated with their roles as anti-inflammatory agents, antimicrobial substances, and compounds with anti-aging properties (de Andrade et al., 2014; Pattananandecha et al., 2021). These generally contribute to health benefits and improve the immune system modulation and potential prevention of chronic conditions like gastrointestinal disorders (Massoud et al., 2024), diabetes (Mendelson et al., 2023), hypertension, and cardiovascular diseases (da Silva Júnior et al., 2022; Kitwetcharoen et al., 2023).

Black tea has been the main ingredient for a long time in the making of kombucha. Recent studies have shown the utilization of other ingredients or other types of tea, like green tea (Fraiz et al., 2024), white tea (Tarhan et al., 2023), yellow tea (Onsun et al., 2025), fruit juices, herbal teas, and dried fruits to increase the health benefits of kombucha (Jayabalan et al., 2014). This research uses purple tea (*C. sinensis* var. *purpurea*, TRK306) and yacon (*Smallanthus sonchifolius*) syrup as ingredients to create a kombucha drink with varied health benefits. These diversification holds promise for promoting climate-resilient indigenous crops that increase dietary diversity to fight undernutrition and micronutrient deficiencies. The development of locally sourced functional beverages aligns well with global initiatives, especially the Sustainable Development Goals (SDG2) of the Food and Agriculture Organization (FAO, 2023). Purple tea, cultivated in Kenya, is known for its high anthocyanin and flavonoid content, offering strong antioxidant potential and cardiovascular benefits (Yan et al., 2024; Maritim et al., 2021).

Purple tea also contains theobromine, a bitter alkaloid that adds to its astringency and boosts the anthocyanin level (Ye et al., 2022). Research has been done on ways to reduce the astringency in purple tea beverages, such as adding fruit and herbs like lemon, ginger, or rosemary. These additives tend to lower anthocyanin content in purple tea leaves (Kilel et al., 2019).

There is also a need to consider the use of yacon as a source of sweetness in the products, among other health benefits. Its use together with purple tea as ingredients may enhance kombucha's nutritional and functional qualities, aligning with health and dietary goals in Sub-Saharan Africa (SSA) (Ndhlovu and Tagutanazvo, 2025).

Yacon, a root-tuber (Caetano et al., 2016), is known for its high levels of fructooligosaccharide (FOS) and inulin, prebiotic compounds that support gut bacteria (Yan et al., 2019). It contains 83 to 90% water. It's a low-energy-value edible fruit, and its non-digestible carbohydrates provide a source of prebiotics for gut bacteria, offering benefits for managing diabetes, constipation, and other conditions (Esatbeyoglu et al., 2023). Adding yacon syrup to products like kombucha improves its sensory appeal, prebiotic, and probiotic benefits (Durães et al., 2021).

The choice of ingredients influences the physico-chemical and sensory profiles of kombucha (Jayabalan et al., 2014).

Other research has been conducted on alternative substrates (Osiripun and Apisittiwong, 2021). However, there is limited information on the combined use of other ingredients, such as purple tea and yacon syrup, in kombucha production. The qualities of kombucha may be affected by other factors, such as storage temperatures. Research shows that storage temperature and duration can significantly affect microbial dynamics in kombucha. The yeasts and acetic acid bacteria stabilize during storage at 4°C and remain stable over 90 days, whereas storage at room temperature leads to a shift in microbial community structure and diminishes probiotic organisms over time, making the beverage unutilized due to changes in taste (Grassi et al., 2022). Hence, there is a need to evaluate the effect of storage conditions on parameters such as pH for kombucha samples. This study characterized the physicochemical properties, sensory qualities, and shelf life studies of kombucha formulated with these novel ingredients, contributing to the development of a functional beverage with enhanced health benefits.

MATERIALS AND METHODS

Sample collection and preparation

The raw materials included yacon tubers, purple tea, SCOBY, and sugar. Yacon was obtained from Dedan Kimathi University of Technology farm. The SCOBY was sourced from Telvian Supplies in Nairobi. Purple tea was acquired from the Kangaita tea farm in Kenya, Kirinyaga County. Sugar and water were purchased from Naivas supermarket in Nyeri. All samples were collected and stored at the food laboratory at Karatina University. The SCOBY was refrigerated at $4 \pm 1^\circ\text{C}$ prior to activation. The study utilized a completely randomized design. The treatments were prepared by combining purple tea and yacon syrup using different ratios, where Treatment A (95:5 for Purple tea: sugar), B (90:10 for purple tea: yacon), C (90:10 for purple tea: yacon), and D (80:15 for purple tea: yacon). The treatments were prepared in triplicate.

Preparation of ingredients

Purple tea infusion was prepared by steeping 500 g of dried orthodox leaves in 1 L of hot water at 70°C for 10 to 15 min, using methods of (Kilel, 2019). 50 kg of yacon tubers were obtained, washed, peeled, and treated with citric acid. It was then chopped into pieces ($\sim 0.5 \times 0.5$ cm) and juiced, extracted, filtered through cheesecloth, and concentrated by boiling at 100°C to achieve a 72°Bx (da Silva et al., 2018). Syrup was cooled and used in preparation for the treatments. Starter cultures were prepared following the method of Phung et al. (2023), with 90 mL batches of sweetened tea inoculated with 10% (v/v) SCOBY.

Preparation of kombucha

Kombucha production from the different formulations was prepared following the methods of Cardoso et al. (2020) and Jayabalan et al. (2014). The different treatments were cooled and inoculated with 100 mL/L of starter culture and covered with cheesecloth to prevent contamination. Fermentation was conducted at ambient temperature (28°C) for 14 days.

Table 1. Physicochemical properties of purple tea kombucha made with yacon syrup.

Treatment	pH level	Total acidity (% w/v)	Brix (°Bx)	Alcohol content (% v/v)	Antioxidant activity (% inhibition)	Polyphenol content (mg/L)
A (Control) 95% purple tea, 5% sugar	4.1 ± 0.10 ^a	0.46 ± 0.01 ^a	6.3 ± 0.1 0 ^a	0.5 ± 0.10 ^a	59 ± 1.00 ^a	149 ± 1.00 ^a
B (95% purpletea, 5% yacon)	4.3 ± 0.10 ^b	0.49 ± 0.01 ^b	7.0 ± 0.1 0 ^b	0.7 ± 0.10 ^b	64 ± 1.00 ^b	159 ± 1.00 ^b
C (90% purpletea, 10% yacon)	4.5 ± 0.10 ^c	0.55 ± 0.01 ^c	7.6 ± 0.10 ^c	0.8 ± 0.1 0 ^c	71 ± 1.00 ^c	171 ± 1.00 ^c
D (80% purpletea, 15% yacon)	4.7 ± 0.10 ^d	0.59 ± 0.01 ^d	8.1 ± 0.10 ^d	1.2 ± 0.10 ^d	79 ± 1.00 ^d	181 ± 1 .00 ^d
p-value (0.05)	0.01	0.02	0.01	0.001	0.001	0.001
HSD (Tukey's)	0.12	0.02	0.12	0.12	1	1

Values expressed as Mean ± SD. Superscript letters ^a, ^b, ^c, ^d denote significant differences among treatment means *($p \leq 0.05$) using Tukey's HSD test.

Physicochemical analysis

The pH was measured using a calibrated digital pH meter (Model pH-700, Eutech Instruments) after diluting 10 mL of each sample with an equal volume of distilled water. Calibration was done with pH 4.0 and 7.0 buffer standards. Titratable acidity (TTA, % w/v) was determined via titration with 0.1 N NaOH and expressed as acetic acid equivalents, following Association of Official Analytical Chemists (AOAC) Official Method 942.15 (AOAC International, 2023). For each sample, 10 mL was diluted with 10 mL of distilled water, and three drops of phenolphthalein were added before titrating with 0.1 N NaOH to a persistent pink endpoint. Soluble solids were assessed in °Brix using a handheld refractometer equipped with automatic temperature compensation. Alcohol content was analyzed using a hydrometer, where calculations were performed as alcohol by volume (ABV%) (Ivory et al., 2021).

Polyphenol and antioxidant activity

the Folin-Ciocalteu method (Guo et al., 2024). A mixture of 0.5 mL sample extract and 2.5 mL of 10% Folin-Ciocalteu reagent was incubated for 5 min, followed by the addition of 20 mL of 7.5% sodium carbonate. After 30 min at room temperature, absorbance was measured at 765 nm using a UV-Vis spectrophotometer (Model 8453, Agilent Technologies). The results were expressed as gallic acid equivalents (GAE) using a standard curve (0-200 mg/L). Antioxidant activity was evaluated using the DPPH radical scavenging assay (Pekkarinen et al., 1999; Munteanu and Apetrei, 2021). Samples were reacted with DPPH solution, and absorbance was recorded at 518 nm. A gallic acid calibration curve (0.6-1.0 mg/mL) was used to express antioxidant capacity as percentage inhibition.

Mineral analysis

Mineral profiling (Ca, Mg, Zn, Fe) was conducted using Atomic Absorption Spectroscopy (AAS) following the methods described by Paul et al. (2014). Samples were filtered, diluted, and lanthanum chloride was added to reduce interference for Ca and Mg. AAS was performed at respective wavelengths: Ca - 422.7 nm, Fe - 248.3 nm, Zn - 213.9 nm, and Mg - 285.2 nm. Certified standards were used for calibration, and concentrations were calculated based on absorbance readings.

Sensory evaluation

Sensory analysis was conducted on day two of storage using 15

semi-trained panelists (aged 18 to 50) from the Tea Institute at Karatina University. Panelists were selected randomly and trained according to ISO 4121:2003 guidelines and sensory protocols described by Grujić et al. (2014) and Drake et al. (2023). The panelist was provided with 15 mL of each sample, given unique codes, and evaluated using a 5-point hedonic scale (1 - dislike extremely to 5 - like extremely). Water and sugarless biscuits were provided for palate cleansing between samples.

Shelflife studies

Shelf life studies were conducted following the procedures of Tran et al. (2025). All kombucha samples for the different treatments were stored under two different storage conditions: room temperature (28°C) and refrigeration temperatures at 4°C. The samples for each formulation were monitored for 30 days to evaluate the stability and quality attributes during storage. Sampling was performed on days 0, 14, and 30, and the pH measurements were taken using a calibrated digital pH meter (Model pH-700, Eutech Instruments), with each sample analyzed in triplicate.

Statistical analysis

Statistical analysis was performed using one-way ANOVA, with significance set at $p < 0.05$. Post-hoc comparisons were performed using Tukey's HSD test. Results are presented as mean ± standard deviation, with coefficients of variation (CV) calculated.

RESULTS AND DISCUSSION

Physicochemical properties of purple tea and yacon syrup formulations

The results for the physicochemical properties for the different treatments are shown in Table 1. Based on the data, all treatments were significantly different ($p \leq 0.05$) in pH values. Treatment A (Control) had the lowest significant pH at 4.1, while Treatment D had the highest significant level at 4.7. The level of pH increased as the amount of yacon increased in the formulations. In the control (Treatment A), with sugar and no yacon added, the yeast

Table 2. Mineral analysis results for kombucha made with purple tea and yacon syrup.

Treatment	Calcium (mg/L)	Zinc (mg/L)	Magnesium (mg/L)	Iron (mg/L)
A (control) 95% purple tea, 5% sugar	12.8 ± 0.10 ^a	2.2 ± 0.05 ^a	8.7 ± 0.10 ^a	0.8 ^a ± 0.05 ^a
B (95% purple tea, 5% yacon)	14.0 ± 0.10 ^a	2.5 ± 0.05 ^a	9.2 ± 0.10 ^a	4.0 ± 0.10 ^b
C (90% purple tea, 10% yacon)	16.5 ± 0.10 ^b	3.0 ± 0.05 ^{ab}	10.0 ± 0.10 ^{ab}	5.2 ± 0.10 ^c
D (80% purple tea, 15% yacon)	19.0 ± 0.10 ^c	3.0 ± 0.05 ^c	11.8 ± 0.10 ^c	6.5 ± 0.10 ^c
P value (0.05)	0.003	0.004	0.002	0.001
HSD	2.1	0.4	0.7	0.6

Values with different superscript letters (^a, ^b, ^c, ^d) within the same column are significantly different from each other at $p < 0.05$ according to Tukey's Honest Significant Difference (HSD) test. Values sharing the same letter are not significantly different.

Table 3. Sensory evaluation of purple tea and yacon syrup.

Treatment	Aroma (Mean ± SD)	Taste (Mean ± SD)	Color (Mean ± SD)	Acceptability (Mean ± SD)
A (control)	4.20 ± 0.42 ^a	3.80 ± 0.35 ^a	4.50 ± 0.40 ^a	4.10 ± 0.30 ^a
B (95% purple tea, 5% yacon)	4.60 ± 0.30 ^{ab}	4.10 ± 0.25 ^{ab}	4.80 ± 0.32 ^b	4.30 ± 0.25 ^{ab}
C (90% purple tea, 10% yacon)	4.80 ± 0.20 ^b	4.30 ± 0.30 ^b	4.70 ± 0.28 ^b	4.50 ± 0.22 ^b
D (80% purple tea, 15% yacon)	4.40 ± 0.35 ^{ab}	4.00 ± 0.32 ^{ab}	4.60 ± 0.30 ^{ab}	4.20 ± 0.28 ^{ab}
P-value (0.05)	0.014	0.018	0.008	0.021
Hsd (Tukey's)	0.41	0.36	0.29	0.33

Values are expressed as Mean ± standard deviation (SD). Superscript letters (^a, ^b) denote statistically significant differences among means based on Tukey's HSD test at $p \leq 0.05$.

stimulation fermentation is limited, resulting in the lowest pH for the control. As the proportion of yacon syrup increases for treatments B to D, yacon seems to provide more fermentable sugars, which increase yeast metabolism, producing compounds that increase the pH. The greater yeast fermentation leads to the production of products like ethanol and organic acids, while also generating compounds like polyphenols from purple tea that act as natural buffers (Chong et al., 2024). This supports the idea that changes in ingredient composition or processing methods impact the fermentation process (Ojo and de Smidt, 2023). A study on black and green tea kombucha found that pH levels dropped from around 5.5 to 3.8 immediately after inoculation, then reached 2.5-3.5 by day seven. Similarly, research on purple basil kombucha recorded a pH of 3.10 ± 0.06 after one day, which decreased to 3.15-3.37 during fermentation (Chong et al., 2024), and alcohol content was low, between 0.5 and 1.2%.

Antioxidant activity varied significantly (59 to 79% inhibition), and polyphenol content, which contributes to health benefits, ranged from 149 to 181 mg/L; both showed significant differences ($p \leq 0.02$). Mineral levels, as shown in Table 2, varied: calcium ranged from 14.29 to 24.77 mmol/L, magnesium from 9.64 to 10.13 mmol/L, zinc from 23.73 to 24.37 mg/g, and iron from 0.0288 to 0.2934 mg/g. The sensory results, presented in Table 3, indicated that the treatment with 90% purple tea and 10% yacon syrup (Treatment C) scored highest, with 4.80 for aroma, 4.30 for

taste, and 4.50 for overall appeal on a 5-point hedonic scale. Shelf life studies, shown in Figures 1 and 2, indicated that storing the kombucha at 4°C in the refrigerator preserved its pH and flavor better than storage at room temperature.

Total acidity

Total acidity values increase consistently from 0.46 for the control to 0.59 in the treatment with the highest yacon incorporation. This indicates that yacon incorporation promoted more organic acid formation in the treatments after fermentation. This is supported by findings of Singh et al. (2022) who indicated that fermentation of yacon produces more organic acids. The fructooligosaccharides (FOS) from yacon may reduce the rate of acidification by slowing fermentation since they are less readily metabolized by the SCOBY compared to sucrose (Yıkımsı and Tuğgüm, 2019). Although limited data exists on the acidity of yacon kombucha, the observed values (0.46-0.59%) are lower than those typically reported for standard kombucha. One study found that purple basil kombucha acidity was between 0.66 and 0.76%, and consistent with the lower end of the usual range (Özyurt, 2020). A study on black tea kombucha measured acetic acid at 1.55 g/L (0.155% w/v), with total acidity likely higher due to other acids (gluconic, citric). Yerba mate kombucha showed acidity of 4.8-6.0% acetic acid after 12 days, far exceeding

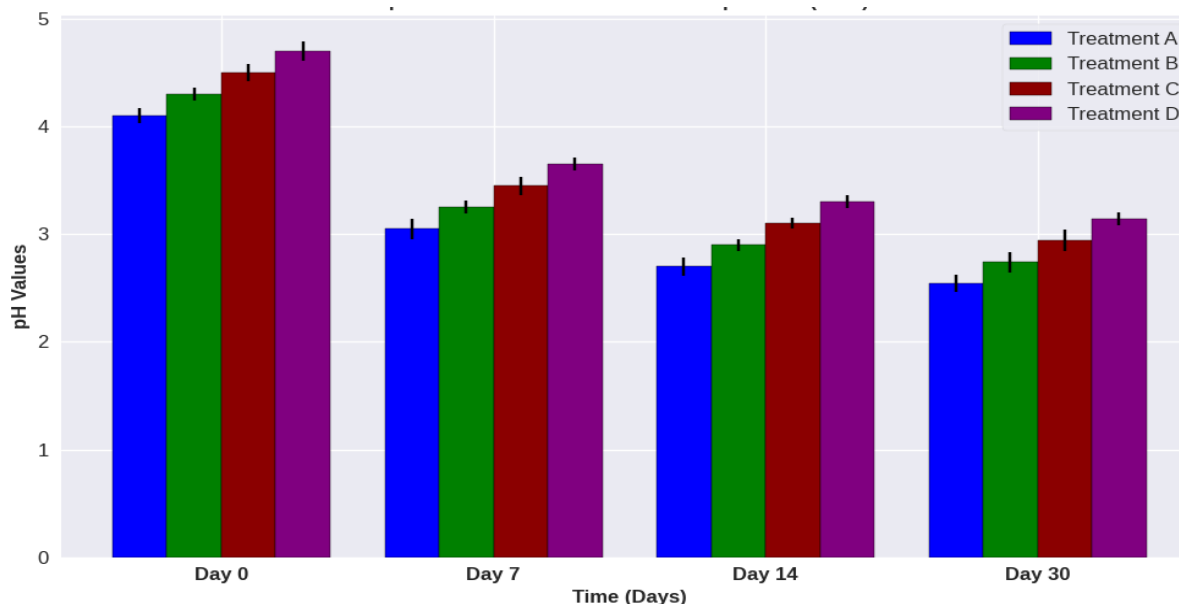


Figure 1. pH value of Kombucha samples stored under A room temperature at 28°C.

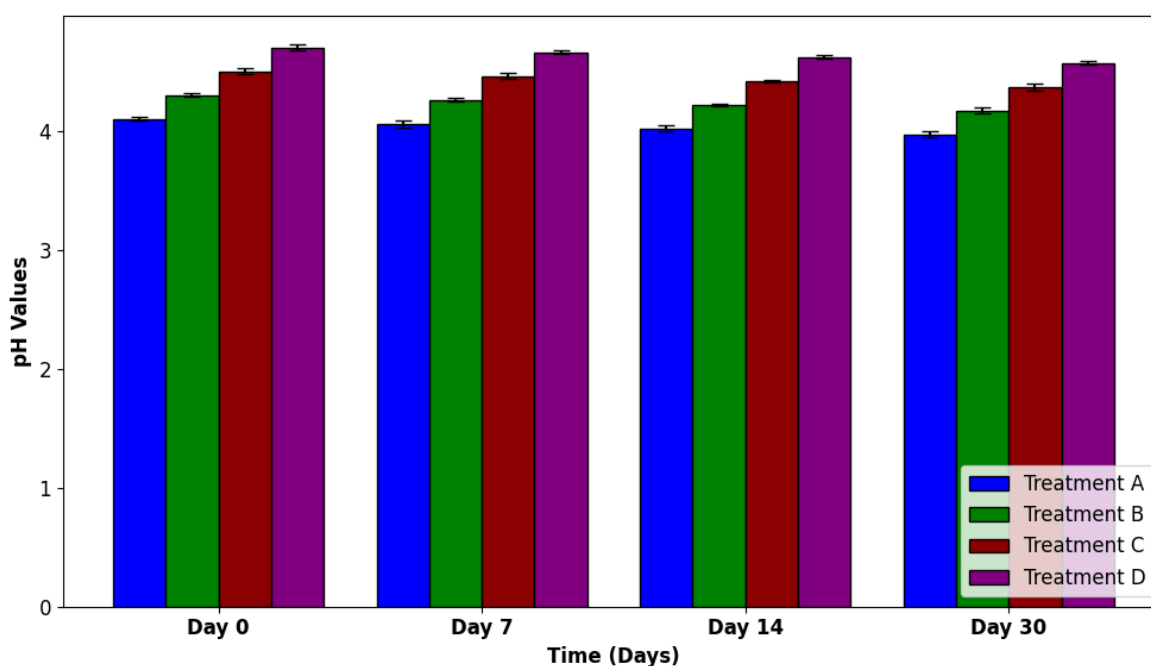


Figure 2. pH value of Kombucha samples stored under refrigeration temperatures at 4°C.

typical values, possibly due to unique substrates (Yıkımsı and Tuğgüm, 2019).

The increase in pH and total acidity reflects the system's enhanced buffering due to added yacon, leading to a greater accumulation of organic acids (total acidity) without a proportional release of free hydrogen ions, hence a higher measured pH (Wiles, 2025).

Brix values

Brix is a measure of soluble solids content expressed as a percentage showed significant differences between the different treatments. The control showed the lowest significant level at 6.3, while the treatment with the highest content of yacon showed the highest significant level of

8.1. During kombucha fermentation, brix typically decreases as bacteria and yeasts break down sugars into ethanol and carbon dioxide. The control with no yacon added had sugars that are readily fermented, hence reducing its soluble solid contents compared to the other treatments with yacon.

The treatments with yacon syrup contain FOS, which are less readily fermented by SCOBY, contributing to residual sugars and elevating the Brix levels in the samples. Additionally, the presence of polyphenols and other bioactive compounds from purple tea may influence microbial metabolism and slow sugar breakdown. In the control, anthocyanins form complexes with sugars and other polyphenols, potentially altering the refractive index and affecting Brix measurements (Yan et al., 2024).

The level of Brix for the different samples was within the range reported by other authors. Some studies have shown initial Brix values for sugar-added tea at 10-12 °Brix, dropping to 5-8 °Brix after 14 days of fermentation (Yıkımlı and Tuğgüm, 2019). For comparison, a study on kombucha fermentation with alternative sweeteners found Brix values ranging from 5.5-7.8 °Brix after 10 days (Zhang et al., 2025). Another recent study on herbal kombucha reported Brix values of 6.0 to 8.5 °Brix (Kayisoglu and Coskun, 2021).

Alcohol content

Alcohol content for the control was 0.5% and increased significantly in the samples with yacon content, reaching 1.2% in the treatment with the highest yacon incorporation. These findings underscore the role of yacon-derived carbohydrates in enhancing ethanol yield, highlighting their fermentability and contribution to alcohol formation during kombucha fermentation (Durães et al., 2021). The results suggest that yacon syrup, rich in fermentable FOS, enhanced microbial fermentation efficiency, leading to higher ethanol yields. These findings align with previous studies indicating that yacon promotes fermentation activity and that kombucha microbes readily convert available sugars into ethanol and organic acids (Neffe-Skocińska et al., 2017).

Antioxidant activity

Antioxidant activity ranged from 59 to 79% for the different treatments. The samples with yacon incorporation showed an increasing trend as the level of yacon also increased. Although the antioxidant activity (ranging from 59 to 79%) it's lower than some tea-based kombuchas, this may be attributed to shorter fermentation periods or the slower microbial activity of yacon. The presence of anthocyanins in purple tea likely boosts the higher activity observed in Treatment D, consistent with findings related to red and green tea kombucha (Jakubczyk et al., 2021). The low CV of 1.69% supports the consistency of measurements,

reinforcing the reliability of these variations. Comparatively, green and red tea kombucha exhibit superior antioxidant activity (for instance, 80 to 90% DPPH inhibition) than black tea, due to their higher polyphenol content. Purple tea's richness in anthocyanins likely elevates antioxidant activity, which may explain the increase from Treatment A (59%) to Treatment D (79%).

Polyphenol content

The control was significantly lower at 149 mg/L and higher for the treatment with the highest proportion of yacon at 181 mg/L. This was consistent with the observations by Singh et al. (2019) which reported that hot water extraction of yacon leaves increased total phenolic content and antioxidant activity, enhancing the cell wall disruption and release of bound phenolics during processing. These phenolic compounds, known for their antioxidant properties, are enhanced through the yacon metabolism and breakdown of plant tissues (Ueda et al., 2021). The high levels were also influenced by the anthocyanin content present in purple tea, while the fructo-oligosaccharides increased microbial activity within the scoby, improving the release of more polyphenols during the fermentation.

Mineral content for the different Kombucha formulations

Calcium (Ca)

The mean calcium content level was 12.8 mg/L in the control (Treatment A) and 19.0 mg/L in Treatment D, the treatment with the highest yacon incorporation (Table 2). The other treatments with yacon incorporation showed an increasing trend as per the increase in yacon proportions. This could be attributed to the yacon's capacity to release bound minerals through enzymatic hydrolysis and chelation processes, improving calcium solubility and bio accessibility (Zhang and Liu, 2022). Similar mineral enrichment during fermentation has also been reported in plant-based beverages, where minerals are liberated from complex matrices (Cao et al., 2018). Dietary fibers inulin and fructans present in yacon are known to foster a more favorable gut environment for mineral uptake by modifying colonic pH and stimulating beneficial gut microbiota (Zhang et al., 2019). Fermentation of yacon-enriched matrices leads not only to higher calcium concentrations but also to improved absorption in simulated gastrointestinal models, suggesting meaningful nutritional benefits in the beverage.

Zinc (Zn)

Zinc levels were also low in control samples at 2.2 mg/L and high in treatments with yacon incorporation.

Treatment D showed a highly significant level at 3.8 mg/L than the other treatments. This high content in yacon-enriched treatments could be due to the combined biochemical effects of yacon syrup and purple tea, which promote zinc release and stability during fermentation. Yacon's FOS improves mineral solubility through chelation. The FOS are known to form soluble complexes with divalent minerals such as zinc, thereby improving mineral solubility and preventing precipitation during processing and storage. Purple tea's polyphenolic compounds enhance zinc stability and boost its antioxidant role by activating superoxide dismutase (Yan et al., 2024). Yacon provides FOS, which are known to form soluble complexes with divalent minerals such as zinc, thereby improving mineral solubility and preventing precipitation during processing and storage (Chessum et al., 2022).

Magnesium (Mg)

Magnesium content showed a similar upward trend as the level of yacon added increased. The control showed a lower level of 8.7 mg/L, and the highest was in treatment D at 11.8 mg/L. The increasing trend as the yacon proportion increased indicates a significant enhancement in magnesium content with each formulation. This increase is attributed to the fermentation-enhanced breakdown of anti-nutritional factors such as phytates, which typically inhibit mineral absorption (Samtiya et al., 2021). Yacon, which is considered to be rich in FOS, promotes microbial enzymatic activity, particularly phytase production that degrades phytates and improves magnesium bio-accessibility (Samtiya et al., 2021). Additionally, magnesium plays a critical role in enzymatic pathways activated during fermentation, including ATP synthesis and cofactor-dependent reactions, which may facilitate its mobilization into solution (Rondón, 2025). Hence, enriching fermentative beverages with yacon not only increases magnesium content but also supports its conversion into more bioavailable forms, contributing to the nutritional value and functional properties of the final product (Samtiya et al., 2021).

Iron (Fe)

Iron levels showed a substantial increase, from the control at 0.8 to 6.5 mg/L in treatment D. This increase is also attributed to fermentation-induced iron solubilization, facilitated by the presence of organic acids and siderophore-like compounds derived from plant-based substrates such as yacon and purple tea. These acid compounds can chelate ferric iron (Fe^{3+}), converting it into more bioavailable ferrous forms (Fe^{2+}), thereby improving mineral extraction and retention in the matrix. Such enrichment is particularly relevant for addressing iron-deficiency concerns in plant-based formulations, where bioavailability is often limited by anti-nutritional factors.

Other recent studies confirm that siderophore-producing microbes and polyphenol-rich ingredients can significantly enhance iron uptake and fortification in functional beverages (Srivastava, 2023; Hegde et al., 2025).

Sensory evaluation of purple tea and yacon syrup kombucha formulations

The sensory parameters evaluated were aroma, taste, color, and acceptability on purple tea and yacon syrup kombucha treatments. All attributes demonstrated statistically significant differences across treatments ($p < 0.05$), suggesting that yacon incorporation strongly influences sensory perception.

Aroma

scores increased from 4.20 in treatment A (control) to a high of 4.80 in treatment C. The treatments with yacon incorporation were not significantly different. This indicates that yacon incorporation contributes favorably to the aromatic profile. This improvement is attributed to the synthesis of esters and volatile alcohols during fermentation, which enriches aroma complexity (Zhu et al., 2025). Treatment D, with a higher yacon proportion, had a slightly lower score of 4.40 may reflect over-fermentation effects or saturation of aromatic compounds, as observed in similar yacon formulations (Calderan et al., 2025). The reduction in aroma and taste observed in Treatment D (15% yacon) suggests possible overproduction of volatile acids or off-flavors associated with extended fermentation or substrate overload, consistent with similar reports on yacon-enriched beverages (Calderan et al., 2025).

Taste

The ratings followed a similar upward trend, rising from 3.80 in the control to 4.30 in treatment C (Table 3). The other treatments with yacon incorporation were not significantly different. The enhancement in taste is linked to yacon enzymatic activity, which generates free amino acids, esters, and organic acids that modulate the flavor profile (Chessum et al., 2022). However, a slight taste decline in treatment D could be due to the accumulation of fermentation byproducts such as higher alcohols or acids, which diminish palatability (Bao et al., 2018). These results indicate a positive impact of yacon addition on the beverage's taste up to a certain concentration, with statistical analysis confirming that treatments with yacon addition had significantly higher taste scores compared to the control.

Color

The color perception was most favorable in treatment B at

4.80 and was not significantly different from that of treatment C (4.70) and treatment D (4.6). The control had the lowest significant score at 4.50 (Table 3). The higher color scores for treatment B show the influence of purple tea anthocyanins, which intensify colour and visual appeal. This enhancement is likely due to the synergistic effects of yacon and purple tea, which contribute to pigment stabilization and increased polyphenol availability during fermentation. Yacon tubers contain phenolic compounds such as chlorogenic and caffeic acids, which are stabilized through enzymatic browning control and matrix interactions (Durães et al., 2021). Fermentation promotes the release and transformation of bound polyphenols, intensifying color and clarity in plant-based beverages (Pan et al., 2025). These mechanisms collectively improve visual appeal and support the functional quality of the final product. These combined mechanisms, matrix-based pigment stabilization, increase polyphenol availability, and controlled enzymatic activity not only brighten the beverage's appearance but also signal high functional and nutritional quality to the consumer. The consistently high color scores reinforce the positive impact of yacon and purple tea inclusion on both the aesthetic and health value of the final product (Chakrabarty et al., 2021).

Overall acceptability

Treatment C showed the highest significant value at 4.50, suggesting that 10% yacon. inclusion offers optimal sensory balance. Overall acceptability scores were 4.10 in the control (Treatment A), 4.30 in Treatment B, 4.50 in Treatment C, and 4.20 in Treatment D (Table 3). Treatment C showed a significantly higher level but was not significantly different from Treatment B and D, but was significantly different from the control.

This demonstrates that acceptability improves with yacon inclusion up to 10%, as seen in treatment with yacon addition, where sensory attributes, including aroma, taste, and color, were most favorably balanced. However, higher concentrations of yacon did not yield further gains of these attributes and showed a slight reduction in consumer preference. This peak acceptability reflects synergistic effects of improved aroma, balanced taste, and vibrant color characteristics that align with consumer preferences for fermented functional beverages (García-Barón et al., 2025).

Temperature and time on pH changes during storage

The shelf-life studies for kombucha samples stored for 30 days exhibited notable differences in pH dynamics depending on whether they were kept at room temperature or under refrigeration. The graph for samples stored in room temperature (28°C) is shown in Figure 1. In this condition, fermentation progressed rapidly, and the pH continued to decrease as the storage period progressed.

By day 14, treatments A and B had reached pH levels between 2.5 and 3.0. By day 30, the pH levels for treatment A and B were 2.54 and 2.74, respectively. This also alters the sensory profiles, resulting in strong tart or vinegary profiles. Although less ideal for drinking, these acidic samples could serve as starter cultures for subsequent brews due to their low pH (Jayabalan et al., 2014). Treatments C and D fermented more slowly, likely due to the lower initial sugar content due to the high proportion of yacon as reflected in their higher pH levels.

The refrigerated(4°C) samples showed a significant increase, maintaining high pH values between 3.6 and 4.0 for the 30 days of storage (Figure 2). This indicates slow fermentation, leading to low production of acids. Hence, the sensory properties are less affected due to low-temperature storage. This helped preserve flavor quality, delay sourness, and reduce risk of spoilage, especially important in polyphenol-rich formulations using purple tea, whose antioxidants may contribute to flavor retention even if they do not directly impact pH (Chen and Liu, 2000). The presence of fructo-oligosaccharides (FOS) in yacon also likely delayed fermentation, contributing to gradual acidification over time (Yan et al., 2024). The non-digestible carbohydrates that selectively nourish beneficial microbes such as *Lactobacillus* and *Bifidobacterium*, which metabolize them more slowly than simple sugars. This slower microbial activity leads to gradual acid production, controlled acidification, and a buffering effect that helps stabilize pH. As a result, the beverage maintains a milder flavor profile and aromatic integrity. In combination with purple tea's antioxidant properties, this contributes to enhanced shelf life, reduced spoilage risk, and improved sensory appeal (Sasi et al., 2025).

Most treatments showed pH dropped below 4.2 by day 7, ensuring microbial safety regardless of storage conditions. However, prolonged room-temperature storage risks over-fermentation and microbiological instability. Thus, for optimal shelf life and balanced taste, refrigeration after 7 to 10 days of fermentation is recommended (Grassi et al., 2022).

Conclusion

The incorporation of yacon into Purple Tea-based formulations significantly enhances their nutritional, functional, sensory, and fermentation properties. As demonstrated across various experiments, increasing yacon concentrations led to elevated levels of antioxidants, polyphenols, and alcohol, while modulating acidity and sweetness, optimizing the beverage's physico-chemical profile. Sensory evaluation revealed that a 10% yeast inclusion (Treatment C) consistently produced superior results in aroma, taste, color, and overall acceptability, suggesting this level achieves the best balance for consumer appeal.

Yacon addition also enriched the mineral content of the formulations, with notable improvements in calcium, zinc,

magnesium, and iron concentrations. This transformation reflects the fermentative action of yacon in liberating bioavailable nutrients, supporting both health benefits and product value. Storage conditions further emphasized the critical role of temperature, where refrigeration effectively preserved flavor stability and controlled acid production over time, while room temperature accelerated fermentation and acidity, impacting drinkability and shelf life.

Together, these findings affirm that yacon is not merely a fermentation agent but a multifunctional enhancer of Purple tea-based beverages, boosting quality, nutrition, and acceptability when carefully formulated and stored. These insights offer valuable guidance for future product development, especially in crafting functional fermented drinks with tailored sensory and nutritional attributes.

ACKNOWLEDGEMENTS

The authors gratefully recognize the academic support from Dedan Kimathi University of Technology and the laboratory resources provided by Karatina University. They also appreciate their supervisor for invaluable guidance throughout this research.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

- AOAC International (2023). Official Method 942.15: Acidity (Titratable) of fruit products. In Official methods of analysis of AOAC International (22nd edition). Rockville, MD: AOAC International. <https://www.aoac.org/official-methods-of-analysis/>
- Bao R, Liu S, Ji C, Liang H, Yang S, Yan X, Zhou Y, Lin X, Zhu B (2018). Shortening fermentation period and quality improvement of fermented fish, Chouguiyu, by co-inoculation of *Lactococcus lactis* M10 and *Weissella cibaria* M3. *Frontiers in Microbiology* 9:3003.
- Barros VC, Botelho VA, Chisté RC (2024). Alternative substrates for the development of fermented beverages analogous to kombucha: an Integrative Review. *Foods* 13(11):1768.
- Caetano BF, De Moura NA, Almeida AP, Dias MC, Sivieri K, Barbisan LF (2016). Yacon (*Smallanthus sonchifolius*) as a food supplement: health-promoting benefits of fructooligosaccharides. *Nutrients* 8(7):436.
- Calderan RP, Zanetti VC, Feiten MC, Fagundes C, Huber E, Gonzalez SL (2025). Development, characterization, and sensory acceptability of typical Brazilian cheese bread premixes formulated with the addition of yacon potato flour. *Plant Foods for Human Nutrition* 80(2):99.
- Cao Y, Ma ZF, Zhang H, Jin Y, Zhang Y, Hayford F (2018). Phytochemical Properties and Nutrigenomic Implications of Yacon as a Potential Source of Prebiotics: Current Evidence and Future Directions. *Foods* 7(4):59.
- Cardoso RR, Neto RO, dos Santos D'Almeida CT, do Nascimento TP, Pressete CG, Azevedo L, Martino HS, Cameron LC, Ferreira MS, de Barros FA (2020). Kombuchas from green and black teas have different phenolic profile, which impacts their antioxidant capacities, antibacterial, and antiproliferative activities. *Food Research International* 128:108782.
- Chakrabarty A, Katoch A, Katoch P (2021). Purple tea, a rich source of anthocyanin and polyphenol: A Review. *Journal of Pharmaceutical Research International* 33(64A):403-414.
- Chen C, Liu BY (2000). Changes in major components of tea fungus metabolites during prolonged fermentation. *Journal of Applied Microbiology* 89(5):834-839.
- Chessum K, Chen T, Kam R, Yan M (2022). A Comprehensive Chemical and Nutritional Analysis of New Zealand Yacon Concentrate. *Foods* 12(1):74.
- Chong AQ, Chin NL, Talib RA, Basha RK (2024). Modelling pH dynamics, SCOBY biomass formation, and acetic acid production of kombucha fermentation using black, green, and oolong teas. *Processes* 12(7):1301.
- da Silva Júnior JC, Mafaldo ÍM, de Lima Brito I, de Magalhães Cordeiro AM (2022). Kombucha: Formulation, chemical composition, and therapeutic potentialities. *Current Research in Food Science* 5:360-365.
- da Silva MD, Dionisio AP, de Abreu FA, de Brito ES, Wurlitzer NJ, e Silva LM, Ribeiro PR, Rodrigues S, Taniguchi CA, Pontes DF (2018). Evaluation of nutritional and chemical composition of yacon syrup using ¹H NMR and UPLC-ESI-Q-TOF-MSE. *Food Chemistry* 245:1239-1247.
- de Andrade EF, de Souza Leone R, Ellendersen LN, Masson ML (2014). Phenolic profile and antioxidant activity of extracts of leaves and flowers of yacon (*Smallanthus sonchifolius*). *Industrial Crops and Products* 62:499-506.
- Drake MA, Watson ME, Liu Y (2023). Sensory Analysis and Consumer Preference: Best Practices. *Annual Review of Food Science and Technology* 14(1):427-448.
- Durães GC, Pires BA, Lins TC (2021). Kombucha-based synbiotic beverage using Yacon (*Smallanthus sonchifolius*) as a fermentation substrate: Development and sensorial analysis. *Food Research* 5(4):66-71.
- Esatbeyoglu T, Sarikaya Aydin S, Gültekin Subasi B, Erskine E, Gök R, Ibrahim SA, Yilmaz B, Özogul F, Capanoglu E (2023). Additional advances related to the health benefits associated with kombucha consumption. *Critical Reviews in Food Science and Nutrition* 64(18):6102-6119.
- Food and Agriculture Organisation (FAO) (2023). Tracking progress on food and agriculture-SDG indicators. Available at <https://openknowledge.fao.org/server/api/core/bitstreams/3a8baf8c-960d-4105-9538-e4bd9b1d4503/content/index.html>
- Fraiz GM, Bonifácio DB, Lacerda UV, Cardoso RR, Corich V, Giacomini A, Martino HS, Esteban-Echeverría S, Romo-Hualde A, Muñoz-Prieto D, Barros FA. (2024). The Impact of Green Tea Kombucha on the Intestinal Health, Gut Microbiota, and Serum Metabolome of Individuals with Excess Body Weight in a Weight Loss Intervention: A Randomized Controlled Trial. *Foods* 13(22):3635
- García-Barón SE, Carmona-Escutia RP, Herrera-López EJ, Leyva-Trinidad DA, Gschaedler-Mathis A (2025). Consumers' drivers of perception and preference of fermented food products and beverages: A Systematic Review. *Foods* 14(5):713.
- Grassi A, Cristani C, Palla M, Di Giorgi R, Giovannetti M, Agnolucci M (2022). Storage time and temperature affect microbial dynamics of yeasts and acetic acid bacteria in a kombucha beverage. *International Journal of Food Microbiology* 382:109934.
- Grujić S, Odžaković B, Ciganović M (2014). Sensory analysis as a tool in the new food product development. *Proceedings of II International Congress Food Technology Quality and Safety* pp. 28-30.
- Guo G, Muhammad T, Aimaiti Z, Dolkun A, Tian M, Zhao Q, Reheman A (2024). Precise evaluation of batch adsorption kinetics of plant total polyphenols based on a flow-injection online spectrophotometric method. *Analytical Methods* 16(4):589-598.
- Ivory R, Delaney E, Mangan D, McCleary BV (2021). Determination of ethanol concentration in kombucha beverages: Single-laboratory validation of an enzymatic method, first action method 2019.08. *Journal of AOAC International* 104(2):422-430.
- Jakubczyk K, Gutowska I, Antoniewicz J, Janda K (2021). Evaluation of fluoride and selected chemical parameters in kombucha derived from white, green, black and red tea. *Biological Trace Element Research*, 199(9):3547-3552.
- Jayabalan R, Malbaša RV, Lončar ES, Vitas JS, Sathishkumar M (2014). A review on kombucha tea—microbiology, composition, fermentation, beneficial effects, toxicity, and tea fungus. *Comprehensive Reviews in Food Science and Food Safety* 13(4):538-550.
- Kayisoglu S, Coskun F (2021). Determination of physical and chemical

- properties of kombucha teas prepared with different herbal teas. *Food Science and Technology* 41(suppl 1):393-397.
- Kilel EC (2019). Optimization of brewing, processing conditions and their effects on the chemical and sensory quality of purple-leafed Kenyan tea (Doctoral dissertation, Egerton University).
- Kilel EC, Wanyoko JK, Faraj AK, Ngoda P (2019). Effect of citric acid on the total monomeric anthocyanins and antioxidant activity of liquor made from unprocessed purple-leafed TRFK 306 Kenyan tea clone. *Food and Nutrition Sciences* 10(10):1191-1201.
- Kitwetcharoen H, Phung LT, Klanrit P, Thanonkeo S, Tippayawat P, Yamada M, Thanonkeo P (2023). Kombucha healthy drink—recent advances in production, chemical composition, and health benefits. *Fermentation* 9(1):48.
- Laureys D, Britton SJ, De Clippeleer J (2020). Kombucha tea fermentation: A review. *Journal of the American Society of Brewing Chemists* 78(3):165-174.
- Maritim TK, Korir RK, Nyabundi KW, Wachira FN, Kamunya SM, Muoki RC (2021). Molecular regulation of anthocyanin discoloration under water stress and high solar irradiance in pluckable shoots of purple tea cultivar. *Planta* 254(5):85.
- Massoud R, Jafari R, Khosravi-Darani K (2024). Kombucha is a health-beneficial drink for human health. *Plant Foods for Human Nutrition* 79(2):251-259.
- Mendelson C, Sparkes S, Merenstein DJ, Christensen C, Sharma V, Desale S, Auchtung JM, Kok CR, Hallen-Adams HE, Hutkins R (2023). Kombucha tea as an anti-hyperglycemic agent in humans with diabetes - a randomized controlled pilot investigation. *Frontiers in Nutrition* 10:1190248.
- Munteanu IG, Apetrei C (2021). Analytical Methods Used in Determining Antioxidant Activity: A Review. *International Journal of Molecular Sciences* 22(7):3380.
- Ndhlovu E, Tagutanazvo EM (2025). African Food Systems: Prospects for Safe Food, Healthy Diets, and Nutrition in Sub-Saharan Africa. In E. Ndhlovu (Ed.), *African Food Systems* (pp. 267-293). Springer Nature Switzerland.
- Neffe-Skocinska K, Sionek B, Scibisz I, Kolozyn-Krajewska D (2017). Acid contents and the effect of fermentation conditions of Kombucha tea beverages on physicochemical, microbiological, and sensory properties. *Cyta-journal of Food* 15(4):601-607.
- Ojo AO, de Smidt O (2023). Microbial composition, bioactive compounds, potential benefits, and risks associated with Kombucha: A concise review. *Fermentation* 9(5):472.
- Onsun B, Toprak K, Sanlik N (2025). Kombucha tea: a functional beverage and all its aspects. *Current Nutrition Reports* 14(1):69.
- Osiripun V, Apisittiwong T (2021). Polyphenol and antioxidant activities of Kombucha fermented from different teas and fruit juices. *Journal of Current Science and Technology* 11(2):188-196.
- Özyurt H (2020). Changes in the content of total polyphenols and the antioxidant activity of different beverages obtained by Kombucha 'tea fungus.' *International Journal of Agriculture Environment and Food Sciences* 4(3):255-261.
- Pan F, Liu X, Qiao M, Liu J, Pang Y, Zhang M, Yu W (2025). Innovative composite systems for enhancing plant polyphenol stability and bioavailability. *Food Science and Biotechnology* 34(9):1819-1834.
- Pattananandecha T, Apichai S, Sirilun S, Julsrigival J, Sawangrat K, Ogata F, Kawasaki N, Sirithunyalug B, Saenjurn C (2021). Anthocyanin profile, antioxidant, anti-inflammatory, and antimicrobial against foodborne pathogens activities of purple rice cultivars in northern Thailand. *Molecules* 26(17):5234.
- Paul BN, Chanda S, Das S, Singh P, Pandey BK, Giri SS (2014). Mineral Assay in Atomic Absorption Spectroscopy. *The Beats of Natural Sciences* 4(1):1-7.
- Pekkarinen SS, Stöckmann H, Schwarz K, Heinonen IM, Hopia AI (1999). Antioxidant activity and partitioning of phenolic acids in bulk and emulsified methyl linoleate. *Journal of Agricultural and Food Chemistry* 47(8):3036-3043.
- Phung LT, Kitwetcharoen H, Chamnipa N, Boonchot N, Thanonkeo S, Tippayawat P, Klanrit P, Yamada M, Thanonkeo P (2023). Changes in the chemical compositions and biological properties of kombucha beverages made from black teas and pineapple peels and cores. *Scientific Reports* 13(1):7859.
- Romualdo GR, De Souza IP, Da Rocha VJD, Dionísio AP, Barbisan LF (2024). Bioactive compounds and biological activities of yacon root (*Smallanthus sonchifolius*) on gut-liver-adipose tissue axis. In Murthy HN, Paek KY, Park SY (Eds.), *Bioactive compounds in the storage organs of plants*. Springer Nature Switzerland pp. 937-958.
- Rondón LJ (2025). Nutritional Factors Affecting Magnesium Bioavailability: A Narrative Review. *Biological Trace Element Research*.
- Samtiya M, Aluko RE, Puniya AK, Dhewa T (2021). Enhancing micronutrients bioavailability through fermentation of plant-based foods: A concise review. *Fermentation* 7(2):63.
- Sasi M, Kumar S, Prakash O, Krishnan V, Vinayaka, Tomar GS, Mishra J, RAS, Kaushik P, Rana VS, Dahuja A (2025). Evaluation of sensory properties and short-chain fatty acid production in fermented soy milk on addition of fructooligosaccharides and raffinose family of oligosaccharides. *Fermentation* 11(4):194.
- Singh S, Srivastava P, Deep S, Ashish, Shukla P, Rizvi H, Sinha R (2022). Fermentation strategies for organic acid production. In *Industrial Microbiology and Biotechnology*. Singapore: Springer Singapore pp. 379-425.
- Singh V, Lehri A, Singh N (2019). Assessment and comparison of the phytoremediation potential of selected plant species against endosulfan. *International Journal of Environmental Science and Technology* 16(7):3231-3248.
- Srivastava N (2023). Siderophore production in iron uptake and plant biofortification. In Chhabra S, Prasad R, Maddela NR, Tuteja N (Eds.), *Plant microbiome for plant productivity and sustainable agriculture*. Springer Nature Singapore pp. 313-329.
- Tarhan KK, Aykut G, Tek S, Yatmaz E, Germec M, Yavuz I, Turhan I (2023). Production and characterization of Kombucha tea from different sources of tea and its kinetic modeling. *Processes* 11(7):2100.
- Tran T, Steyer D, Verdier F, Martin A, Alexandre H, Grandvalet C, Tourdot-Maréchal R (2025). Field investigation of flavored kombucha's shelf life unveils high sensitivity of microbial dynamics towards assimilable nitrogen. *Food and Bioprocess Technology* 18(1):370-391.
- Ueda Y, Matsuda Y, Murata T, Hoshi Y, Kabata K, Ono M, Kinoshita H, Igoshi K, Yasuda S (2021). Investigation of total polyphenol content, antioxidant activity, and carbohydrate-hydrolyzing enzyme inhibition of yacon leaves among four domestic cultivars and a peru line for over four years. *Japan Agricultural Research Quarterly: JARQ* 55(4):347-358.
- Wiles H (2025). Kombucha Fermentation: The impact of gel-immobilised cells on ph, sugar metabolism, and organic acid production. In Graham AM, Hawks M, Hayes G (Eds.), *2025 QUT Faculty of Science Vacation Research Experience Scheme*. Queensland University of Technology.
- Yan M, Huang X, Xie N, Zhao T, Zhu M, Li J, Wang K (2024). Advances in Purple Tea Research: Chemical Compositions, Anthocyanin Synthesis and Regulation, Processing, and Health Benefits. *Horticulturae* 10(1):50.
- Yan MR, Welch R, Rush EC, Xiang X, Wang X (2019). A sustainable wholesome foodstuff, health effects and potential dietotherapy applications of yacon. *Nutrients* 11(11):2632.
- Ye JH, Ye Y, Yin JF, Jin J, Liang YR, Liu RY, Tang P, Xu YQ. (2022). Bitterness and astringency of tea leaves and products: Formation mechanism and reducing strategies. *Trends in Food Science and Technology* 123:130-143.
- Yıkımlı S, Tuğgüm S (2019). Evaluation of Microbiological, Physicochemical, and Sensorial Properties of Purple Basil Kombucha Beverage. *Turkish Journal of Agriculture - Food Science and Technology* 7(9):1321-1327.
- Zhang JQ, Li C, Huang Q, You LJ, Chen C, Fu X, Liu RH (2019). Comparative study on the physicochemical properties and bioactivities of polysaccharide fractions extracted from *Fructus Mori* at different temperatures. *Food and Function* 10(1):410-421.
- Zhang M, Liu K (2022). Calcium supplements and structure-activity relationship of peptide-calcium chelates: A review. *Food Science and Biotechnology* 31(9):1111-1122.
- Zhu YT, Ma Q, Zhang XY, Gong GZ, Wang YX, Zeng LZ, Li RT, Xiao C, Zuo Y (2025). Functional yacon juice fermented by *Lactiplantibacillus plantarum* QST7: Chemical composition, flavor volatiles, and gut microbiota modulation. *Journal of Food Science* 90(2):e17528.