Journal of Food Research; Vol. 14, No. 1; 2025
ISSN 1927-0887 E-ISSN 1927-0895
Published by Canadian Center of Science and Education

Yacon Prebiotic Functional Beverages, the Sensory, Antioxidant Profiles, and Shelf Stability

Mary R. Yan[1, 2], Keegan Chessum[3], Saleshni Nand[1] & Rothman Kam[3]

[1] Healthcare and Social Practice, Unitec Institute of Technology, Auckland, New Zealand

[2] AUT Food Network, Auckland University of Technology, Auckland, New Zealand

[3] Food Science and Microbiology, Auckland University of Technology, Auckland, New Zealand

Correspondence: Mary Yan, Healthcare and Social Prectice, Unitec Institute of Technology, PO Box 92025, Carrington Rd, Auckland 1025, New Zealand. Tel: 0064-9-8928465. E-mail: myan@unitec.ac.nz

Received: February 16, 2024 Accepted: September 13, 2024 Online Published: September 23, 2024

doi:10.5539/jfr.v14n1p13 URL: https://doi.org/10.5539/jfr.v14n1p13

Abstract

The increasing awareness on overall health of consumers has driven a shift from fruit juices and carbonated beverages to functional beverages. This research aimed to incorporate yacon concentrate to the formulation of functional beverages to improve the health-related properties. Using yacon concentrate as main ingredients, three functional prototypes have been developed: yacon-collagen, yacon-blackcurrant, and yacon-vitamin c. Sensory evaluation for yacon-collagen and yacon-blackcurrant beverages was conducted by a 9-point hedonic scale. Antioxidant activities of three yacon beverages were evaluated using the CUPRAC, DPPH, and FRAP assays. Yacon-collagen and yacon-blackcurrant beverages were sensory acceptable with ratings above the centre point of the scores (all ratings > 5, n = 50) on four sensory attributes (appearance, sweetness, flavor, overall liking). The antioxidant capacity of yacon-collagen, yacon-blackcurrant, yacon-vitamin c, and yacon concentrate were 1941mg/2300mg/1891mg/1193mg TE/100g (CUPRAC), 1943mg/2404mg/2122mg/1365mg TE/100g (DPPH), and 1219mg/2614mg/2990mg/992mg TE/100g (FRAP). The antioxidant capacity of yacon-blackcurrant and yacon-vitamin c were much higher than that of yacon concentrate because blackcurrant and vitamin c enhanced the antioxidant capacity. The development of yacon functional beverages with acceptable taste, verified health-related properties, applicable shelf-life, as new dietotherapy applications of yacon concentrate, could provide more healthier food products for consumers to exercise healthier food choices.

Keywords: yacon, prebiotics, fructo-oligosaccharides (FOS), sensory, antioxidant

1. Introduction

The increasing awareness on overall health of consumers has driven a shift from fruit juices and carbonated beverages to functional beverages (Miller et al., 2020; Tahmassebi & BaniHani, 2020). Most of fruit juices and energy beverages in the market are high in sugar content (Boulton et al., 2016; Sugajski, Buszewska-Forajta, & Buszewski, 2023). Functional beverages, utilize new ingredients (e.g., prebiotics and probiotics) have now created a niche in the food and beverage industry.

Prebiotics foster the growth and activity of microorganisms and moderate the composition of the beneficial microorganisms in the gut microbiota, e.g., bifidobacteria and lactobacilli (Fonteles & Rodrigues, 2018; Hughes, Alvarado, Swanson & Holscher, 2022). Prebiotic dietary fibre has been widely used in the production of functional beverages for the fortification of a range of health benefits including the prevention and alleviation of type 2 diabetes, cardiovascular disease, hypertension and stroke (Gunenc, Hosseinian & Oomah, 2017). However, depending on the type of the fibre, the derivation process involves either extractions, chemical modifications, enzymatic hydrolysis, or a combination of two or more (Dhingra, Michael, Rajput & Patil, 2012).

Yacon (*Smallanthus sonchifolius*), a perennial plant of the family Asteraceae native to the Andean regions of South America, is an abundant source of prebiotic fructo-oligosaccharides (FOS) (Cao et al., 2018). Introduced into New Zealand as a garden curiosity in the 1980's, yacon has been established as a commercial crop in the country for almost twenty years. Yacon are grown in Whangarei yacon farm, yacon fruits are harvested after the first autumn or winter frosts and made into yacon juice concentrate (Figure 1) with high pressure low temperature processes to reserve the bioactive components (Yan, Welch, Rush, Xiang & Wang, 2019). Compared

with commercial FOS, natural yacon FOS has more favorable effects in colonic health maintenance (Utami et al., 2013; Yan et al., 2019). In an *in vivo* experiment on rats, comparing yacon tuber with commercialized FOS for twenty-eight days, a two-fold greater concentration of fecal short-chain fatty acids, and lower serum triglycerides were observed in the yacon diet group (Utami et al., 2013). Yacon concentrate NZFOS+, a natural prebiotic, could improve gut bacterial balance, digestive health, and immunity (Yan et al., 2019). Furthermore, its high content of phenolic compounds could present considerable antioxidant properties (de Almeida Paula, Abranches & de Luces Fortes Ferreira, 2015; Delgado, Tamashiro, Marostica Junior & Pastore, 2013; Yan et al., 2019). In 2022, yacon juice concentrate NZFOS+ was awarded Nutra Ingredients Asia Awards.

Our previous study reported that yacon concentrate contains high phenolic compounds with proven antioxidant capacities (Chessum, Chen, Kam & Yan, 2022). Currently, yacon concentrate is consumed as supplements. This research project aimed to incorporate yacon concentrate to the formulation of functional beverages that are health benificial. The sensory attributes (appearance, sweetness, flavor, and overall linking), antioxidant capacity, and the shelf stability of the developed beverages were evaluated. We hypothesized that yacon concentrate could be used in new dietotherapy applications such as prebiotic functional beverages with acceptable taste, verified health-related properties, and applicable shelf-life, to provide more healthier food products for consumers.

Yacon plant

Yacon fruits

Yacon concentrate

Figure 1. Yacon plant, yacon fruits, and yacon concentrate (photos: Yacon New Zealand)

2. Method

2.1 The Formulation of Yacon Prebiotic Functional Beverages

An initial assessment of the alternative product formats for yacon was performed by Yacon New Zealand Ltd. Then, the product types were defined, potential ingredients were selected, and the formulas were tested.

The main ingredients were collagen powder, blackcurrant powder, organic blueberry juice, and yacon concentrate NZFOS+. They are perceived as beneficial to health. Collagen infused functional beverage is a new form in the beverage industry because collagen consumption is efficacious for the improvement of skin aging (Asserin, Lati, Shioya & Prawitt, 2015). Blackcurrant is rich in bioactive compounds associated with health promoting properties such as anti-inflammatory, antioxidant and lowering the glycemic index of foods (Lee & Lee, 2019; Mofasser Hossain, Brennan, Mason, Guo & Brennan, 2017). Blueberry contains a high content of polyphenols associated with health benefits such as antioxidant, anticancer, anti-inflammatory, and antidiabetic effects (Duan et al., 2022; Stote et al., 2017; Tobar-Bolanos, Casas-Forero, Orellana-Palma & Petzold, 2021).

The yacon concentrate was provided by Yacon New Zealand Ltd. Other ingredients were purchased online: collagen powder (Puraz New Zealand Ltd, New Zealand); blackcurrant powder (Healthspan, New Zealand supplier); organic blueberry juice (Monavale Blueberries Ltd, New Zealand); vitamin c (Reactive supplements, New Zealand); kiwi blue spring water; potassium sorbate (E202) (Pure Ingredients Ltd, New Zealand).

Formulation trials were conducted in a commercial kitchen at Unitec Institute of Technology, Auckland. The features considered were color, taste, suspension, and shelf stability.

Three functional prototypes have been developed: yacon-collagen, yacon-blackcurrant, and yacon-vitamin c for school children. The yacon-collagen ingredients were yacon concentrate, collagen (4 g per serving), organic blueberry juice, and spring water; the yacon-blackcurrant ingredients were yacon concentrate, blackcurrant powder (300mg per serving), organic blueberry juice, and spring water; the yacon-vitamin c ingredients were yacon concentrate, vitamin c powder (40 mg per serving), organic blueberry juice, and spring water. The content

of collagen, blackcurrant, and vitamin c in the formula was referred to the recommended daily intake. In the prototypes, 6 g of yacon concentrate NZFOS+ per serving (50 ml) was added for yacon-collagen and yacon-blackcurrant, 3 g of yacon concentrate NZFOS+ per serving (50 ml) was added for yacon-vitamin c. A daily intake of 20 g of FOS or less in human is generally considered safe (Genta, Cabrera, Grau & Sanchez, 2005; Yan et al., 2019). Organic blueberry juice was added to improve the sensory acceptability. The ratio of organic blueberry juice and spring water was adjustable.

2.2 Sensory Evaluation

Consumer acceptance of functional beverages on taste is often a challenge because the high content of bioactive compounds (Skapska et al., 2020). Of themselves, collagen powder has a light smell from the origin source, the taste is challenging for consumers to fully accept. Blackcurrant powder has a sharp aftertaste. Therefore, organic blueberry juice was added to the formulas to improve the overall palatability of the prototypes.

Sensory evaluation was conducted to evaluate yacon-collagen and yacon-blackcurrant prototypes. For each prototype, three samples were prepared with slightly differences in ratios of organic blueberry juice and spring water. The samples were kept in the refrigerator at around 4 °C for testing. Fifty participants were recruited from Unitec Institute of Technology, Auckland. They were staff and students. The staff recruited as participants were not involved in the study. The criteria were people aged 18 years or older, have no known allergies to food ingredients including fructose, collagen, and fructo-oligosaccharides FOS. The prototype samples of 20 ml were served in plastic cups labelled with three-digit random numbers and served at room temperature. The participants were asked to taste and describe the difference between the three samples of each prototype beverage in terms of appearance, sweetness, flavor, and overall liking, and rated their perceptions on the ballot (Figure 2). The attributes were scored by a structured 9-point hedonic scale from 1 (very slight perception) to 9 (very intense perception) (Wichchukit & O'Mahony, 2015). Water was provided to participants to rinse their mouth between samplings. Ethical approval was obtained from Unitec Research Ethics Committee (2022-1041). All participants signed a consent form prior to the test.

		Appearance	Sweetness	Flavor	Overall
☺	Like extremely	☐	☐	☐	☐
	Like a lot	☐	☐	☐	☐
	Like moderately	☐	☐	☐	☐
	Like slightly	☐	☐	☐	☐
	Neither like nor dislike	☐	☐	☐	☐
	Dislike slightly	☐	☐	☐	☐
	Dislike moderately	☐	☐	☐	☐
	Dislike a lot	☐	☐	☐	☐
☹	Dislike extremely	☐	☐	☐	☐
	Any comments?				

Figure 2. Ballot for yacon functional beverages with four sensory attributes: appearance, sweetness, flavor, and overall linking

From the sensory evaluation results, two formulas with highest ratings (one for yacon-collagen and one for yacon-blackcurrant) were chosen for further measurements together with the formula of yacon-vitamin c. The prototype of yacon-vitamin c was developed for school children, the sensory evaluation was not conducted.

2.3 pH Measurement

The pH values of yacon-collagen, yacon-blackcurrant, and yacon-vitamin c prototypes were determined using a digital pH meter (Eutech pH 700 meter, Thermo Fisher Scientific, USA.), each sample was measured in triplicates. The pH meter was calibrated prior to measurement.

2.4 Antioxidant Activity

The antioxidant activity of the developed prototype beverages (yacon-collagen, yacon-blackcurrant, yacon-vitamin c) were evaluated using the cupric reducing antioxidant capacity (CUPRAC) (Chessum et al., 2022), ferric-ion reducing antioxidant power (FRAP) (Chessum et al., 2022) and 2,2-diphenyl-1-picrylhydrazyl (DPPH) (Chessum et al., 2022) assays in beverage form. In addition, they were compared with yacon juice concentrate NZFOS+ to assess whether low pH or other factors in the formulation may potentially affect the antioxidant capacity (Fonteles & Rodrigues, 2018). All reagents used for the antioxidant assays are ≥ 99 % purity.

Methanol, ethanol, ammonium acetate, and sodium acetate trihydrate were sourced from Fisher Scientific, UK. Concentrated hydrochloric acid (36 %) and glacial acetic acid was purchased from Ajax Finechem, Australia. Iron (III) chloride was sourced from Scharlau Chemie, Spain. Copper sulphate dihydrate, neocuporine, 2,4,6-tripyridyl-S-triazine, 2,2-di(4-tert-octylphenyl)-1-picrylhydrazyl, and 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox, 97 %) were sourced from Sigma-Aldrich, USA. The three assays were used to measure the antioxidant activity to prevent false positive measurements. External calibration Trolox solution with concentration ranging from 5 to 160 mg L^{-1} were prepared. The results were expressed in mg of Trolox equivalents (TE) per 100 g.

2.5 Shelf Stability Based on Color Change

The shelf stabilities of the prototypes were tested by monitoring the color change at different storage temperature (accelerated shelf-life test). Four hei-VAP value digital water baths (Heidolph Instruments, Germany) were set up at 30, 40, 50, 60 °C, respectively. A 25 ml sample of each yacon prototype beverage was placed in a 100 ml Schott bottle. The samples were diluted to 12 Brix and the absorbance was measured according to their wavelength. An initial UV wavelength scan (Ultrospec 7000 spectrophotometer, UK) on the yacon beverages showed they had the strongest absorbance at 330 nm for yacon-collagen, 558 nm for yacon-blackcurrant, and 450 nm for yacon-vitamin c. The initial absorbances were recorded at time zero (t = 0) samples. Then the samples were placed in the four water baths throughout a 2-week storage period. Three samples of each beverage were prepared for each temperature condition. The absorbances were evaluated daily for color change. The shelf-life of the beverage was determined to be acceptable as long as the change in absorbance (color) did not exceed 10 %. It is reported that the color change of 10 % and below in a food system is not noticeable (Wibowo, Buvé, Hendrickx, Loey & Grauwet, 2018). The reaction rate constants and activation energies are also presented in the Supplementary Information.

2.6 Statistical Ananlysis

The results of sensory and antioxidant activity were expressed as mean ± standard error (SE). Statistical analysis was carried out by R statistical software version 1.1.463. The significance of the difference between mean values of variables was performed with a one-way analysis of variance and means comparison (post hoc Tukey's test). For shelf-life test, the absorbances were plotted versus time at 30, 40, 50, 60 °C on the same plot to determine the reaction rate constants at each temperature, then to determine the activation energy for browning.

3. Results

Three functional prototypes were developed. They were yacon-collagen, yacon-blackcurrant, and yacon-vitamin c.

3.1 Sensory Evaluation

Fifty participants participated in the sensory evaluation for yacon prebiotic functional beverages. Three formulas of yacon-collagen and three formulas of yacon-blackcurrant were evaluated. The results indicated that the developed yacon-collagen and yacon-blackcurrant beverages were sensory acceptable with ratings above the centre point of the scores (all ratings > 5, n = 50) on four sensory attributes (appearance, sweetness, flavor, and overall liking), from the just-right-centre-choice point of view (Li, Hayes & Ziegler, 2014). There were no significant differences in ratings on four attributes (p > 0.05) among the three formulas of yacon-collagen, and among the three formulas of yacon-blackcurrant. The formulas of prototypes with highest scores (Table 1, one for yacon-collagen and one for yacon-blackcurrant) from sensory evaluation were chosen for further measurements together with the formula of yacon-vitamin c. Yacon-vitamin c was developed for school children, and the main ingredients were vitamin c and organic blueberry juice (taste acceptable in general). Therefore, sensory evaluation had not been conducted.

Table 1. Sensory evaluation for the prototype beverages from consumer study (n = 50)

Product[1]	Yacon-collagen	Yacon-blackcurrant
Sensory attribute	Mean (SE)	
Appearance	5.06 (0.20)	7.06 (0.19)
Sweetness	6.20 (0.23)	6.30 (0.18)
Flavor	5.96 (0.26)	6.08 (0.19)
Overall liking	6.10 (0.23)	6.40 (0.17)

Sensory evaluation was conducted for yacon-collagen and yacon-blackcurrant prototypes using a structured 9-point hedonic scale. The values were means (SE, standard errors). [1] The yacon-collagen ingredients were yacon concentrate, collage, organic blueberry juice, and spring water; the yacon-blackcurrant ingredients were

yacon concentrate, blackcurrant powder, organic blueberry juice, and spring water.

3.2 pH Measurement

The pH values of the three beverages were 4.69 (yacon-collagen), 4.29 (yacon-blackcurrant), and 3.74 (yacon-vitamin c), respectively. The pH value of yacon-vitamin c was lower than that of other two prototypes.

3.3 Antioxidant Activity

The antioxidant activity of three prototypes were measured and compared with yacon concentrate NZFOS+. The antioxidant activity of yacon-collagen, yacon-blackcurrant, yacon-vitamin c beverages, and yacon concentrate were 1941mg, 2300mg, 1891mg, 1193mg TE/100g (CUPRAC assay), 1943mg, 2404mg, 2122mg, 1365mg TE/100g (DPPH assay), and 1219mg, 2614mg, 2990mg, 992mg TE/100g (FRAP assay), respectively. All three prototypes had higher antioxidant activity compared to yacon concentrate. In particular, the antioxidant capacity of yacon-blackcurrant and yacon-vitamin c were significantly higher than that of yacon concentrate across the three assays (Figure 3).

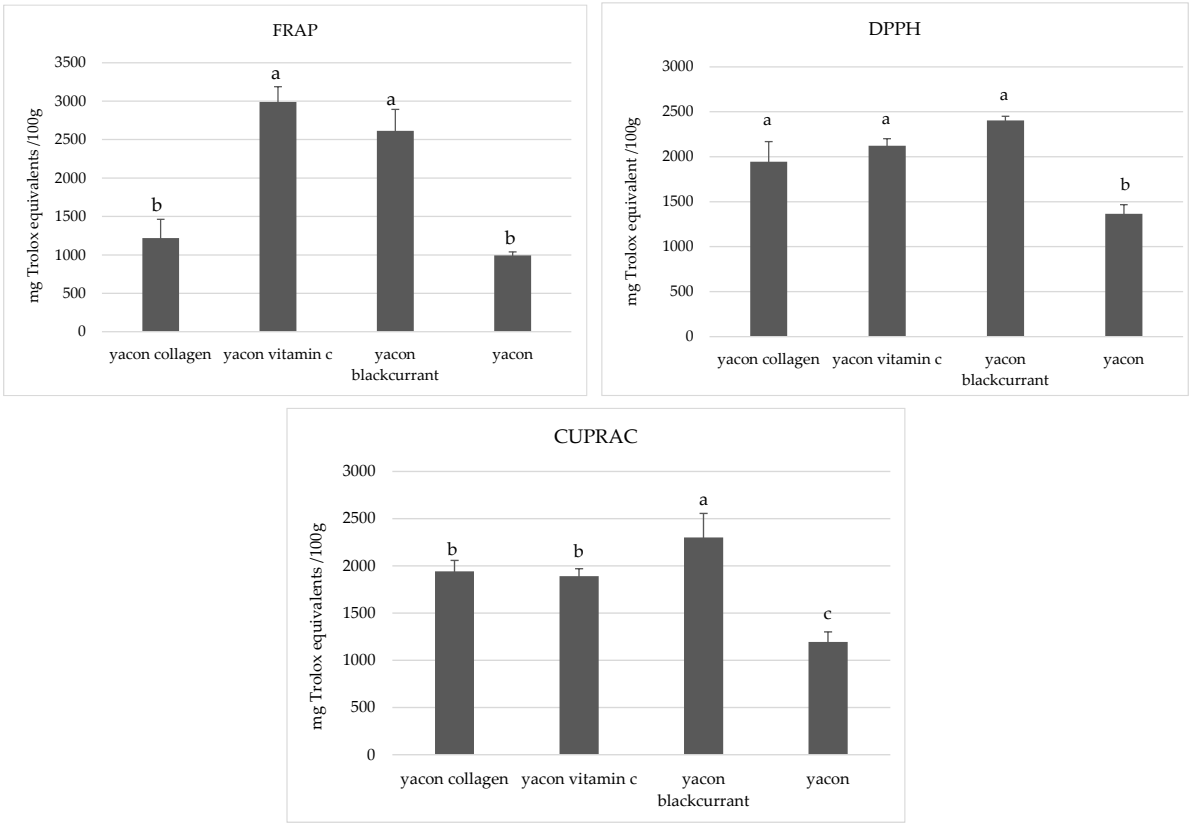

Figure 3. Antioxidant activity of the developed yacon-based beverages compared to yacon concentrate (n = 3). Different letters above bars indicate significant differences ($p < 0.05$)

3.4 Shelf Stability

The results from accelerated shelf-life test revealed that the color change of all the yacon prototype beverages followed zero order reaction. The shelf-life of yacon-collagen and yacon-blackcurrant prototype beverages were more than one year (> 1yr) at room temperature (25 °C) assuming the color does not exceed 10 % change compared to the initial reading (refer to Supplementary Information for kinetics calculations). However, the shelf-life of yacon-vitamin c was approximately three months at room temperature, it needed to be refrigerated for a longer shelf-life (e.g., to be stored at 4 °C for one year shelf-life) (Table 2).

Table 2. Shelf-life of the developed yacon-based beverages at different temperatures: 30, 40, 50, 60 °C (n = 3)

Product	Shelf-life[1] (month)	
	Room temperature (25 °C)	Refrigerated (4 °C)
Yacon collagen	50	
Yacon blackcurrant	13	
Yacon vitamin c	3	18

[1] Shelf-life of the prototypes were tested by monitoring the color change at different storage temperature (accelerated shelf-life test). The yacon-collagen ingredients were yacon concentrate, collage, organic blueberry juice, and spring water; the yacon-blackcurrant ingredients were yacon concentrate, blackcurrant powder, organic blueberry juice, and spring water; the yacon-vitamin c ingredients were yacon concentrate, vitamin c, organic blueberry juice, and spring water.

4. Discussion

The consumption of fruit juices and energy beverages lead to unhealthy diets that have been associated with non-communicable diseases (Boulton et al., 2016). Therefore, development of functional beverages with health-related properties is important to improve public health in the food and beverage industry.

In the study, yacon concentrate NZFOS+ was incorporated to the beverage formulas as natural prebiotics. Three functional prototypes were developed: yacon-collagen, yacon-blackcurrant, and yacon-vitamin c for school children. Yacon concentrate is currently used as a dietary supplement. Development of functional beverages using yacon concentrate as an ingredient could promote yacon concentrate and provide more healthier food choices to our consumers (Chessum et al., 2022), since yacon concentrate was recognized as Nutra ingredients.

Sensory evaluation in new product development is a measure for quality assurance from the marketing perspective. For functional foods, the high content of bioactive compounds often challenges consumer acceptance on taste (Ruiz-Capillas & Herrero, 2021; Skapska et al., 2020). Hence, the nature of the products, nutritional information of the products, and the perceived health-related properties could influence the acceptance of potential consumers (Ruiz-Capillas & Herrero, 2021). For example, collagen is beneficial for the health of bone, tissue, and skin (Hastaoglu, Hastaoglu, Baglam & Tas, 2023); blackcurrant is beneficial for blood pressure (Huang, Chen, Liao, Zhu & Xue, 2016) and blood sugar level (Mofasser Hossain et al., 2017); and yacon FOS, a natural prebiotic, is beneficial for blood sugar level, immunity, and gut microbial balance (Caetano et al., 2016; Khajehei, Merkt, Claupein & Graeff-Hoenninger, 2018; Yan et al., 2019). In this study, participants' age and gender were not included in the sensory evaluation, the results indicated that the yacon prebiotic functional prototypes were acceptable by general consumers.

The antioxidant capacity of yacon-blackcurrant and yacon-vitamin c were significantly higher than that of yacon concentrate NZFOS+. Blackcurrant powder has a high content of phenolic compounds that associated with a considerable antioxidant capacity (Hui et al., 2021; Mofasser Hossain et al., 2017). Vitamin c (ascorbic acid) is an essential antioxidant that is widely used in beverage formulation (Liu, Liu & Li, 2020; Nowak, Goslinski, Wojtowicz & Przygonski, 2018). Hence, in the formulation, blackcurrant and vitamin c enhanced the antioxidant capacity of the yacon prebiotic functional prototypes.

The shelf stability of food is part of the product development process and is important for launching a new food product. The common concerns are color change, microbiological degradation and oxidation (Calligaris, Manzocco, Anese & Nicoli, 2016). Color is an important attribute that has strong influence on consumers' food choice and purchasing behavior (Buvé et al., 2018). Hence, the accelerated shelf-life testing on color change of the prototype beverages was carried out in this study. The mechanism of color change in the yacon-collagen and yacon-vitamin c beverages was most likely due to a combination of oxidation and Maillard reaction (non-enzymatic brown) because under thermal treatment, beverages exhibited a darkening in color over time as shown by the increase in absorbance (Supplementary Information). This aligns with other kinetics studies on color changes of fruit juices, e.g., color degradation of pineapple puree (Chutintrasri & Noomhorm, 2007). The mechanism of color change for the yacon-blackcurrant beverage was caused by color degradation through the destruction of anthocyanins by thermal processing (Patras, Brunton, O'Donnell & Tiwari, 2010). During the accelerated shelf-life testing, it was observed that the yacon-blackcurrant beverage started to change from dark purple to orange color that was an indication of monomeric anthocyanins (Harbourne, Jacquier, Morgan & Lyng, 2008). Harbourne et al. (Harbourne et al., 2008) reported that the degradation in color (measured with UV absorbance of 550 nm) in blackcurrant juice followed a pseudo first-order reaction scheme. Whereas the

yacon-blackcurrant beverage in this study was better modeled with a zero-order reaction. The discrepancy might be due to the influence of pigmentation from the yacon concentrate. In the current study, the yacon-vitamin c prototype had a three-month shelf-life at room temperature. It was relatively short compared to the other two prototypes, though its pH vale was low (pH = 3.74). The possible reason might be the stability of vitamin c in water, e.g., degradation in liquid form (Yin et al., 2022). The stability of vitamin c could be improved by adding other antioxidants in the food matrix (Yin et al., 2022).

There were limitations in the study. The microbial analysis for the prototype beverages was not conducted. The sensory evaluation for yacon-vitamin c prototype was not conducted. The future work for the study is to conduct the real time shelf-life test or conduct microbiological analysis with the yacon functional beverages produced in a GMP production facility, design the packaging, and make the yacon prebiotic functional beverages commercially available.

5. Conclusions

In the present study, we incorporated yacon concentrate to the formulas to produce yacon prebiotic functional beverages. The experimental trials revealed that all the developed functional prototypes had high antioxidant capacities. The sensory evaluation indicated the prototypes were acceptable by general consumers. In addition, the prototypes were shelf stable, though yacon-vitamin c needed to be stored at low temperature for one-year shelf-life.

The study was a proof of concept that the development of yacon functional beverages with acceptable taste, verified health-related properties, and applicable shelf-life, as new dietotherapy applications of yacon concentrate NZFOS+, could provide more healthier food products for our consumers to exercise healthier food choices.

Acknowledgments

The experimental trials for the antioxidant activity and accelerated shelf-life were conducted in a food laboratory at Auckland University of Technology. Also, we would like to thank B. Terzaghi for helping with sensory data collection.

Authors contributions

Dr M.Y. and Dr R.K. were responsible for conceptualization; Dr M.Y., Dr R.K., and K.C. were responsible for methodology; M.Y. and S.N. were responsible for data collection - sensory; K.C. was responsible for data collection - antioxidant activity and accelerated shelf-life; Dr M.Y. and Dr R.K. drafted the manuscript and revised it. All authors read and approved the final manuscript.

Funding

This research was co-funded by Unitec Institute of Technology and Yacon New Zealand Ltd. (RI22002).

Competing interests

The authors declare no conflict of interest.

Informed consent

Informed consent was obtained from all subjects involved in the sensory study.

Ethics approval

The Publication Ethics Committee of the Canadian Center of Science and Education.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

References

Asserin, J., Lati, E., Shioya, T., & Prawitt, J. (2015). The effect of oral collagen peptide supplementation on skin moisture and the dermal collagen network: evidence from an ex vivo model and randomized, placebo-controlled clinical trials. *J Cosmetic Dermatology, 14*(4), 291-301. https://doi.org/10.1111/jocd.12174

Boulton, J., Hashem, K. M., Jenner, K. H., Lloyd-Williams, F., Bromley, H., & Capewell, S. (2016). How much sugar is hidden in drinks marketed to children? A survey of fruit juices, juice drinks and smoothies. *BMJ Open, 6*(3), e010330. https://doi.org/10.1136/bmjopen-2015-010330

Buvé, C., Kebede, B. T., Batselier, C. D., Carrillo, C., Pham, H., Hendrickx, M., … Loey, A. V. (2018). Kinetics of colour changes in pasteurised strawberry juice during storage. *Journal of Food Engineering, 216*, 42-51. https://doi.org/10.1016/j.jfoodeng.2017.08.002

Caetano, B. F., de Moura, N. A., Almeida, A. P., Dias, M. C., Sivieri, K., & Barbisan, L. F. (2016). Yacon (Smallanthus sonchifolius) as a food supplement: health-promoting benefits of fructooligosaccharides. *Nutrients, 8*(7). https://doi.org/10.3390/nu8070436

Calligaris, S., Manzocco, L., Anese, M., & Nicoli, M. C. (2016). Shelf-life assessment of food undergoing oxidation-A review. *Crit Rev Food Sci Nutr, 56*(11), 1903-1912. https://doi.org/10.1080/10408398.2013.807222

Cao, Y., Ma, Z. F., Zhang, H., Jin, Y., Zhang, Y., & Hayford, F. (2018). Phytochemical properties and nutrigenomic implications of yacon as a potential source of prebiotic: current evidence and future directions. *Foods, 7*(4). https://doi.org/10.3390/foods7040059

Chessum, K., Chen, T., Kam, R., & Yan, M. (2022). A comprehensive chemical and nutritional analysis of New Zealand yacon concentrate. *Foods, 12*(1). https://doi.org/10.3390/foods12010074

Chutintrasri, B., & Noomhorm, A. (2007). Color degradation kinetics of pineapple puree during thermal processing. *Food Science and Technology, 40*(2), 300-306. https://doi.org/10.1016/j.lwt.2005.11.003

de Almeida Paula, H. A., Abranches, M. V., & de Luces Fortes Ferreira, C. L. (2015). Yacon (Smallanthus sonchifolius): a food with multiple functions. *Crit Rev Food Sci Nutr, 55*(1), 32-40. https://doi.org/10.1080/10408398.2011.645259

Delgado, G. T., Tamashiro, W. M., Marostica Junior, M. R., & Pastore, G. M. (2013). Yacon (Smallanthus sonchifolius): a functional food. *Plant Foods Hum Nutr, 68*(3), 222-228. https://doi.org/10.1007/s11130-013-0362-0

Dhingra, D., Michael, M., Rajput, H., & Patil, R. T. (2012). Dietary fibre in foods: a review. *J Food Sci Technol, 49*(3), 255-266. https://doi.org/10.1007/s13197-011-0365-5

Duan, Y., Tarafdar, A., Chaurasia, D., Singh, A., Bhargava, P. C., Yang, J., … Awasthi, M. K. (2022). Blueberry fruit valorization and valuable constituents: A review. *Int J Food Microbiol, 381*, 109890. https://doi.org/10.1016/j.ijfoodmicro.2022.109890

Fonteles, T. V., & Rodrigues, S. (2018). Prebiotic in fruit juice: processing challenges, advances, and perspectives. *Current Opinion in Food Science, 22*, 55-61. https://doi.org/10.1016/j.cofs.2018.02.001

Genta, S. B., Cabrera, W. M., Grau, A., & Sanchez, S. S. (2005). Subchronic 4-month oral toxicity study of dried Smallanthus sonchifolius (yacon) roots as a diet supplement in rats. *Food Chem Toxicol, 43*(11), 1657-1665. https://doi.org/10.1016/j.fct.2005.05.007

Gunenc, A., Hosseinian, F., & Oomah, B. D. (2017). Dietary fiber-enriched functional bverages in the mrket. In F. Hosseinian, B. D. Oomah, & R. Campos-Vega (Eds.), *Food & Nutraceuticals: From Plant to Gut* (pp. 45-71). Wiley-Blackwell.

Harbourne, N., Jacquier, J. C., Morgan, D. J., & Lyng, J. G. (2008). Determination of the degradation kinetics of anthocyanins in a model juice system using isothermal and non-isothermal methods. *Food Chemistry, 111*(1), 204-208. https://doi.org/10.1016/j.foodchem.2008.03.023

Hastaoglu, F., Hastaoglu, E., Baglam, N., & Tas, I. N. (2023). Sensorial and nutritional properties of a

collagen-fortified snack bar designed for the elderly. *Nutrients, 15*(16). https://doi.org/10.3390/nu15163620

Huang, H., Chen, G., Liao, D., Zhu, Y., & Xue, X. (2016). Effects of berries consumption on cardiovascular risk factors: A meta-analysis with trial sequential analysis of randomized controlled trials. *Sci Rep, 6*, 236. https://doi.org/10.1038/srep23625

Hughes, R. L., Alvarado, D. A., Swanson, K. S., & Holscher, H. D. (2022). The prebiotic potential of inulin-type fructans: A systematic review. *Adv Nutr, 13*(2), 492-529. https://doi.org/10.1093/advances/nmab119

Hui, X. D., Wu, G., Han, D., Gong, X., Wu, X. Y., Tang, S. Z., … Brennan, C. S. (2021). The effects of bioactive compounds from blueberry and blackcurrant powder on oat bran pastes: enhancing in vitro antioxidant activity and reducing reactive oxygen species in lipopolysaccharide-stimulated raw264.7 macrophages. *Antioxidants (Basel), 10*(3). https://doi.org/10.3390/antiox10030388

Khajehei, F., Merkt, N., Claupein, W., & Graeff-Hoenninger, S. (2018). Yacon (Smallanthus sonchifolius Poepp. & Endl.) as a novel source of health promoting compounds: antioxidant activity, phytochemicals and sugar content in flesh, peel, and whole tubers of seven cultivars. *Molecules, 23*(2). https://doi.org/10.3390/molecules23020278

Lee, Y., & Lee, J. Y. (2019). Blackcurrant (Ribes nigrum) extract exerts an anti-inflammatory action by modulating macrophage phenotypes. *Nutrients, 11*(5). https://doi.org/10.3390/nu11050975

Li, B., Hayes, J. E., & Ziegler, G. R. (2014). Just-about-right and ideal scaling provide similar insights into the influence of sensory attributes on liking. *Food Qual Prefer, 37*, 71-78. https://doi.org/10.1016/j.foodqual.2014.04.019

Liu, Y., Liu, C., & Li, J. (2020). Comparison of vitamin C and its derivative antioxidant activity: evaluated by using density functional theory. *ACS Omega, 5*(39), 25467-25475. https://doi.org/10.1021/acsomega.0c04318

Miller, C., Ettridge, K., Wakefield, M., Pettigrew, S., Coveney, J., Roder, D., ... Dono, J. (2020). Consumption of sugar-sweetened beverages, juice, artificially-sweetened soda and bottled water: an Australian population study. *Nutrients, 12*(3). https://doi.org/10.3390/nu12030817

Mofasser Hossain, A. K. M., Brennan, M. A., Mason, S. L., Guo, X., & Brennan, C. S. (2017). The combined effect of blackcurrant powder and wholemeal flours to improve health promoting properties of cookies. *Plant Foods Hum Nutr, 72*(3), 280-287. https://doi.org/10.1007/s11130-017-0619-0

Nowak, D., Goslinski, M., Wojtowicz, E., & Przygonski, K. (2018). Antioxidant properties and phenolic compounds of vitamin C-rich juices. *J Food Sci, 83*(8), 2237-2246. https://doi.org/10.1111/1750-3841.14284

Patras, A., Brunton, N. P., O'Donnell, C., & Tiwari, B. K. (2010). Effect of thermal processing on anthocyanin stability in foods; mechanisms and kinetics of degradation. *Trends in Food Science & Technology, 21*(1), 3-11. https://doi.org/10.1016/j.tifs.2009.07.004

Ruiz-Capillas, C., & Herrero, A. M. (2021). Sensory analysis and consumer research in new product development. *Foods, 10*(3). https://doi.org/10.3390/foods10030582

Skapska, S., Marszalek, K., Wozniak, L., Szczepanska, J., Danielczuk, J., & Zawada, K. (2020). The development and consumer acceptance of functional fruit-herbal beverages. *Foods, 9*(12). https://doi.org/10.3390/foods9121819

Stote, K. S., Sweeney, M. I., Kean, T., Baer, D. J., Novotny, J. A., Shakerley, N. L., ... Gottschall-Pass, K. T. (2017). The effects of 100% wild blueberry (Vaccinium angustifolium) juice consumption on cardiometablic biomarkers: a randomized, placebo-controlled, crossover trial in adults with increased risk for type 2 diabetes. *BMC Nutr, 3*, 45. https://doi.org/10.1186/s40795-017-0164-0

Sugajski, M., Buszewska-Forajta, M., & Buszewski, B. (2023). Functional beverages in the 21st century. *Beverages, 9*(1). https://doi.org/10.3390/beverages9010027

Tahmassebi, J. F., & BaniHani, A. (2020). Impact of soft drinks to health and economy: a critical review. *Eur Arch Paediatr Dent, 21*(1), 109-117. https://doi.org/10.1007/s40368-019-00458-0

Tobar-Bolanos, G., Casas-Forero, N., Orellana-Palma, P., & Petzold, G. (2021). Blueberry juice: Bioactive compounds, health impact, and concentration technologies-A review. *J Food Sci, 86*(12), 5062-5077. https://doi.org/10.1111/1750-3841.15944

Utami, N. W., Sone, T., Tanaka, M., Nakatsu, C. H., Saito, A., & Asano, K. (2013). Comparison of yacon (Smallanthus sonchifolius) tuber with commercialized fructo-oligosaccharides (FOS) in terms of physiology, fermentation products and intestinal microbial communities in rats. *Biosci Microbiota Food Health, 32*(4), 167-178. https://doi.org/10.12938/bmfh.32.167

Wibowo, S., Buvé, C., Hendrickx, M., Loey, A. V., & Grauwet, T. (2018). Integrated science-based approach to study quality changes of shelf-stable food products during storage: A proof of concept on orange and mango juices. *Trends in Food Science & Technology, 73*, 76-86.

Wichchukit, S., & O'Mahony, M. (2015). The 9-point hedonic scale and hedonic ranking in food science: some reappraisals and alternatives. *J Sci Food Agric, 95*(11), 2167-2178. https://doi.org/10.1002/jsfa.6993

Yan, M. R., Welch, R., Rush, E. C., Xiang, X., & Wang, X. (2019). A sustainable wholesome foodstuff; health effects and potential dietotherapy applications of yacon. *Nutrients, 11*(11), 2632. https://doi.org/10.3390/nu11112632

Yin, X., Chen, K., Cheng, H., Chen, X., Feng, S., Song, Y., & Liang, L. (2022). Chemical stability of ascorbic acid integrated into commercial products: A review on bioactivity and delivery technology. *Antioxidants (Basel), 11*(1). https://doi.org/10.3390/antiox11010153