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Quality enhancement of fermented vegetable juice by probiotic through fermented yam juice using *Saccharomyces cerevisiae*

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Abstract

As the demand for probiotic foods continues to increase and lactose intolerance is common, it is necessary to develop a range of non-milk probiotic beverages. The purpose of this study was to evaluate the preparation process of fermented probiotic beverages using various vegetables as raw materials, and to evaluate the chemical and organoleptic properties of the mixed fermented vegetable juices. The mixed fermented vegetable juice was a beverage obtained by mixing the vegetable juice (purple cabbage, tomato and carrot) fermented by Lactobacillus plantarum and the yam juice fermented by the yeast in an appropriate ratio. During lactobacillus fermentation (48 hours at 30 °C), the cell count of Lactobacillus plantarum increased from 7.49 ± 0.21 log CFU/mL to 9.13 ± 0.19 log CFU/mL ($p < 0.05$), the glucose decreased from 8.924 g/L to 5.528 g/L, and the pH decreased from 5.03 to 3.62. Oxidation activity slightly decreased. The lactic acid and titratable acid/total acid content increased, and the trend of change was similar. During the yeast fermentation (28 °C, 24h), the glucose was almost depleted and ethanol was accumulated. GC-MS analysis showed that microbial fermentation had a significant effect on volatile components. The sensory evaluation results showed that the proper mixing of fermented vegetable juice and fermented yam juice had a significant increase in taste, odor and overall acceptance of the product. The mixed fermented vegetable juice has the potential to adapt to the consumer groups and has in-depth research value.

Keywords: *Lactobacillus plantarum*; vegetable juice; *Saccharomyces cerevisiae*; chinese yam; probiotic fermentation; sensory evaluation.

Practical Application: New fashioned non-dairy fermented beverages from vegetable and Chinese yam were developed.

1 Introduction

As one of the important sources of nutrients and bioactive substances for the human body, vegetables have been widely recognized gobally (Carrillo et al., 2014). Nutrients are rich in vegetables and its research significance and nutritional value continue to be explored (Liu, 2003). Nowadays, the consumer's concern is no longer limited to nutrition and health, but is more concerned with taste. Polyphenols, carotenoids and vitamins in vegetables are closely related to human nutrition and health (García-Alonso et al., 2015). For example, it was found the anthocyanin in purple cabbage is not toxic to human, and it is helpful in cardiovascular disease prevention, immune regulation and cardioprotection (Kruger et al., 2014; Landete et al., 2014). According to clinical studies, the increase of tomato consumption is related to the risk reduction of cardiovascular diseases and cancer diseases, and the effects of carotene and lycopene in tomato on hepatic lipid metabolism are significant (Palomo et al., 2010).

Chinese Yam is a perennial herb that serves as a good source of nutrient supply and staple foods in the world. In China, yam is also used to treat diseases, which is considered to have the effect of regulating gastrointestinal function, invigorating the spleen, keeping the stomach, promoting lung health according to Chinese Medicine, and reducing the spleen and stomach (Hsu et al., 2006). Yam has a high levels of vitamin C, dietary fiber, vitamin B 6, potassium and manganese, and low on saturated fat and sodium. The tubers of yam contain choline, mucin, allantoin, crude fat, crude fiber, phytosterols and steroidal saponins (Chiu et al., 2013), which have many important pharmacological functions such as promoting cell proliferation, reducing plasma glucose, inhibiting microbial activity, and improving myocardial infarction (Jayachandran et al., 2009; Lee et al., 2010).

Probiotics are living microorganisms, and when the number of probiotics reaches a certain level, they will bring health benefits to the host (Hill et al., 2014). According to Balthazar et al. (2018), eating products containing both probiotics and prebiotics can regulate the balance of the intestinal flora, inhibit the growth of pathogens, and promote the health of the body. Yeast and lactic acid bacteria are widely used in the fermentation industry, especially lactic acid bacteria, which are commonly used in the production of dairy products in the beverage industry (Saad et al., 2011). In recent years, lactic acid bacteria has also been added to some juice drinks to produce probiotic beverages. Lactic acid fermentation can not only change the flavor of beverages, but also effectively maintain the nutrition and safety of vegetables. Yeast is widely used in the production of fermented wines and distilled spirits and can produce a series of trace volatile flavour metabolites (Hu et al., 2018). The fermentation of purple cabbage,

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carrots and tomatoes with lactic acid bacteria can effectively reduce the unpleasant odor of cabbage and improve the flavor of vegetable juice. The fermentation of yam juice can effectively reduce the sugar content and maintain the yam efficacy ingredients, which helps consumer low-sugar intake. Blending the two types of beverages can not only improve the flavor of the beverage, but also increase the diversity of beverages (Yang et al., 2018).

The main purpose of this study is to produce fermented vegetables juice that are most acceptable to consumers under the optimal nutrition conditions. Since the organoleptic properties of vegetable juices are relevant to consumer acceptance (Beaulieu et al., 2015), this study discussed the effects of fermentation on sensory characteristics and examined the volatile compounds of vegetable juices before and after fermentation. Because lactic acid bacteria can be beneficial to human health as a probiotic, the growth and survival of them in fermented vegetable juices were analyzed, and the chemical properties of the product (pH, titratable acidity, residual sugar, alcohol content, and lactose) were evaluated. There has been no study to evaluate the effect of adjusting the sensory characteristics of consumers after lactic acid fermentation and yeast fermentation. This work will help to increase the application potential of probiotics and provide reference for the development of new fermented beverages.

2 Methods

2.1 Vegetable juice

Fresh purple cabbage, carrots and tomatoes were purchased in the local market, taken to the laboratory immediately after purchase, and tested within 24 hours (Simsek et al., 2014). Fresh leaves were selected from Purple cabbage., and, The leaves were cleaned and blanched at 85 °C for 60s, then they were soaked in 0.8% w/w citric acid solution for 5 min, and rinsed with drinking water. The pretreated leaves were finally processed in a Juicer with agition 18000 rpm, min 60s by adding drinking water (two volumes of leaves), (Midea, MJ-BL25B2, made in China). Carrots and tomatoes were separately washed by tap water, chopped, and blanched at 95 °C for 60s, then soaked in 0.6% w/w citric acid solution for 10 min (Martínez-Flores et al., 2015), rinsed with water again. The pretreated carrots and tomatoes were blended with drinking water with a ratio of 1:2, respectively, and crushed in Juicer with 18000 rpm, min 60s (Midea, MJ-BL25B2, made in China).

2.2 Chinese yam juice

Fresh yams were purchased at the local market. After testing, the edible portion contains water 77%, starch 17.02%, fiber 1.5%, protein 1.58%, and other ingredients 2.9%. The yam was peeled, rinsed with water and steamed at 105 °C for 20 minutes, added with drinking water at a ratio of 1:1.5, and smashed into a syrup in a juicer with agitation 18000 rpm, min 45s (Midea, MJ-BL25B2, made in China).

2.3 Microorganism and inoculum preparation

The yeast and Lactobacillus plantarum strains used in this work belong to Key Lab of Industrial Microbiology, College of Biotechnology, Tianjin University of Science and Technology (China), and were stored at -80 °C with 20% (v/v) glycerol. To prepare the inoculum, yeast strains were serially sub-cultured in YPD broth pH 6.5 at 30 °C .The Lactobacillus plantarum strain was preserved with 20% (v/v) glycerol at -80 °C and was activated with 100 mL MRS broth medium (Tang et al., 2017). The initial pH of the medium was around 6.5 and cultured at 30 °C for 18 hours.

2.4 Fermented Vegetable Juice (FVJ)

Different proportions of vegetable juices were mixed and then they were subjected to sensory analysis to determine the best ratio. Previous survey results showed that when 60% purple cabbage juice, 30% tomato juice, and 10% carrot juice were mixed, the sensory evaluation value was optimal after 48 hours of fermentation with *L.plamtarum*. The determined optimum mixed vegetable juice was pasteurized at 85 °C for 15-20 min, and then cooled to 30-35 °C (Nematollahi et al., 2016). And 5% (volume fraction) of bacteria solution added to vegetable juice for fermentation (30-35 °C, 48h).

2.5 Fermented Yam Juice (FYJ)

After initial experiments, it was determined that 2U/g alpha-amylase (from novozymes, enzyme activity ≥ 150,000 U/mL) was added to the yam slurry and incubated at 90 °C for 60 minutes. When the temperature was lowered to 58 °C, 180 U/g of amyloglucosidase (from novozymes, enzyme activity ≥ 290,000 U/mL) was added and maintained for 6 hours. After the yam juice was cooled to 28 °C, yeast was added for fermentation (each milliliter of yam juice contains 10^6-10^7 yeast).

2.6 Viable cell count determination

The number of viable cells in the fermented vegetable juice (log CFU/mL) was determined by plate count method using MRS medium (Mortazavian et al., 2007). Viable cell counts were obtained by serial dilution with sterile peptone water until 10^{-6} dilution. Aliquots of 0.1 mL of dilution were plated, in triplicate in plates containing MRS Agar (spread plate method). The plates were incubated for 48 h at 30 °C. Plates containing 30-300 colonies were measured and recorded as colony forming units (CFU) per 1 mL of solution (Wang & Lan, 2015).

2.7 Sensory evaluation (Panda et al., 2017)

Sensory attributes of lacto-juice (taste, aroma, colour/appearance, Overall impression) were evaluated using a 9-point Hedonic scale (where1 = dislike extremely and 9 = like extremely) by a 50 member panellists (25 men and 25 women, aged 20-35 years) selected from students, staff and faculty members of the Department of Biotechnology and Food Technology, of our University who were familiar with organoleptic analysis. Samples were served in clean transparent glasses (tumblers), which had been labelled with three digit random numbers. Questionnaires and water for rinsing between each tasting were provided. The mixed fermented juice developed from vegetables were presented before the panel for sensory analysis. Another set of the same mixed fermented juice samples was evaluated as a replication the following day.

2.8 Biochemical analysis

The pH was determined using the pH 4.0 and 6.86 buffer calibrated digital pH meter (Ion meter 155, Corning Inc, Corning, NY, USA). The titration acidity (TA) was titrated with 0.1 N NaOH solution (Horwitz, 1984) and the lactic acid content was determined by liquid chromatography (Duarte et al., 2011). A portable refractometer (PAL-79S, ATAGO Inc, Guang Zhou, China) was used to measure soluble solids content (SSC) in fermented beverages.

2.9 Antioxidant capacity

The antioxidant capacity of fermented vegetable juice was determined by the spectrophotometric method as described by Hegazy and Ibrahim (Hegazy & Ibrahium, 2013) with some modifications. The results were expressed as ascorbic acid content (AA) mg/100 mL juice. All assays were performed in triplicate and the experiments were done in duplicate (Nadeem et al., 2018).

2.10 Gas chromatography mass spectrometry (GC-MS) analysis (Di Cagno et al., 2009; Menezes et al., 2016)

The absorbed volatiles were desorbed in a splitless mode at 250 °C for 4 minutes into the inlet of a GC (7890A; Agilent Technologies). The GC was equipped with an HP-5 column (60 m × 0.32 mm × 0.25 μm). The column temperature program was 40 °C for 2 minutes, and then raised to 180 °C at 4 °C/min for 2 min; then raised at 6 °C/min to 230 °C for 5 min. Helium was used as a carrier gas and a constant pressure mode of 70 kPa is set. The GC was coupled to an MS detector (5975C; Agilent Technologies, Inc.) used in scan mode (m/z 35-500) with an electron energy of 70 eV. The temperature of the quadrupole, ion source and transmission line was 150 °C, 230 °C and 250 °C, respectively.

2.11 Statistical analysis

All determinations were carried out in triplicate and one-way analysis of variance (ANOVA) was employed to analyze the data using SPSS software (SPSS Software for Windows release 17.0 SPSS Inc., Chicago, IL, USA).Results were expressed as mean values ± standard deviation. Values of $P < 0.05$ were considered as statistically significant (Nadeem et al., 2018).

3 Results and discussion

3.1 The growth of lactobacillus plantarum during fermentation

The growth trend of Lactobacillus plantarum in vegetable juice is shown in Figure 1. Plant lactic acid bacteria can enter the stationary phase within 24 hours, and the total fermentation time is generally less than 48 hours. The specific fermentation time depends on when to enter the decline period (Jaiswal & Abughannam, 2013). It was consistent with the growth of Lactobacillus in this experiment. The initial probiotic concentration was 7.49 ± 0.21 log CFU/mL. After 16h fermentation, the probiotic concentration was increased to 9.04 log CFU/mL during stationary phase, and there was no significant change in cell concentration afterwards fermentation. According to previous reports (Champagne et al., 2015; Yoon et al., 2006), cabbage was studied, and the maximum cell concentration was reported to be between 7 log CFU/mL and 8 log CFU/mL. Yoon (performed fermentation of tomato juice, and the concentration of probiotic cells exceeded 8 log CFU/mL after 48 hours from Yoon et al. (2004) study by fermenting tomato juice. The maximum cell concentration of probiotics in the mixed vegetable juice during fermentation was 9.13 ± 0.19 log CFU/mL in this study, which was in agreement with the reported results. Available literature confirms that purple cabbage (Batista et al., 2011), tomatoes, and carrots are rich in carbohydrates, proteins, inorganic salts, and trace elements necessary for the growth of microorganism (Nazzaro et al., 2008; Pereira et al., 2011). Therefore, it is predicted that the nutrient in the vegetable juice is sufficient to maintain the metabolism and reproduction of the microorganism, and no nutritional supplement of the vegetable juice is required.

In vegetable juices, glucose is the most important sugar, which provides energy for the growth and metabolism of probiotics. This result is consistent with previous research results (Rosa et al., 2001). In the fermentation process of vegetable juice, the number of bacteria gradually increased, while the glucose decreased rapidly. After fermentation of 24 hours, the glucose content decreased from the initial 8.924 g/L to 5.528 g/L, and the glucose consumption was 38.05%. After 48 hours, the glucose content decreased to 3.925 g/L. It shows that LAB has the glucophilic nature (Jaiswal & Abughannam, 2013).

3.2 Analysis on the chemical composition of fermented vegetable juice

For the best fermentation results, microbial fermentation experiments should be performed under optimal conditions. Initial pH and temperature are closely related to microbial growth and metabolism. Mayra Garcia Maia Costa, who studied with Lactobacillus casei fermented pineapple juice, had determined that the microbial activity was highest at the initial of pH of 5.8 and 31 °C (Costa et al., 2013). It was reported that red ginseng extract was fermented with Lactobacillus plantarum at pH 7.45 and 31 °C (Jung et al., 2019). Seyed Mohammad Bagher

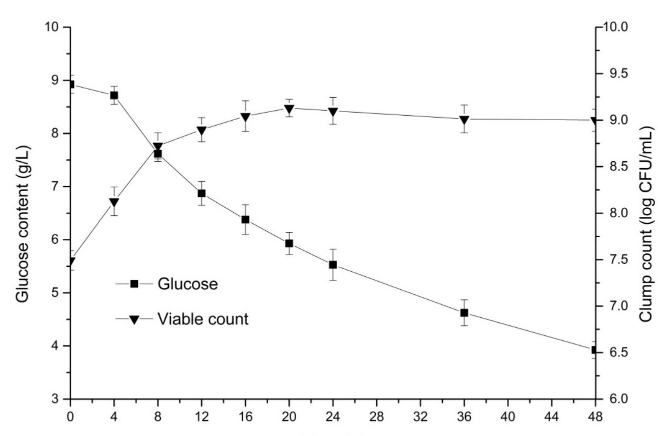

Figure 1. The variation of glucose and colony number.

Hashemi ferments Citrus limetta with Lactobacillus plantarum. The optimum fermentation conditions were pH 3.4 and 37 °C (Hashemi et al., 2017). Therefore, the optimal processing conditions (initial natural pH value and 30 °C) for microbial viability were selected and the juice fermentation changes within 48 h were evaluated. The pH, lactic acid content, and titratable acid (calculated based on lactic acid) content of vegetable juice were shown in Figure 2A. The pH drop slowly in the first four hours,and but it dropped rapidly from 4 h to 8 h . Finally the pH stabilized after the 8 h. The main reason for the drop of pH was due to the production of organic acids. The total acid content in vegetable juice was 0.12 g/L. The total acid content during the fermentation process increased slowly in the first 4 h, and then increased steadily and rapidly. At the end of fermentation, the total acid content reached 10.70 g/L. The increase of lactic acid content was rapid from 4 h to 8 h. The increase rate of lactic acid content was higher than that of total aci from 4 h to 8 h but they were similar after after 4 h.

In addition, because acidic conditions cannot inhibit the growth of LAB but the growth and reproduction of pathogens will be restricted it can prevent other microorganisms from being contaminated and ensure the quality and safety of fermented products (Palomino et al., 2015). In combination with Figure 1, it was shown that glucose was used as the main available carbon source in vegetable juices during fermentation to produce lactic acid (Eş et al., 2018). In fermented vegetable juice, lactic acid was the main organic acid, and the content of lactic acid in total acid was shown in Figure 2B. With the accumulation of lactic acid, the proportion of lactic acid in the total acid gradually increased. Initially, the lactic acid content was 0 g/L. In the late fermentation stage, the lactic acid content reached 9.76 g/L, accounting for 91.19% of the total acid content. The changes in soluble solids content of vegetable juice during fermentation were shown in Figure 2C.

After 24 hours of fermentation, the soluble solids content decreased from 2.5 °Brix to 1.8 °Brix. On the other hand, the influence of fermentation on biologically active compounds was also evaluated. It is well-known that there is plenty of AA in vegetables., but it was very easy to decompose, even if vegetables which stored under normal conditions will cause loss of AA (Del Caro et al., 2004). During the fermentation of vegetable juice, the content of AA decreased significantly from 12.58 mg/100 mL to 6.87 mg/100 mL. Even when vegetables were treated and polyphenol oxidase and peroxidase had been

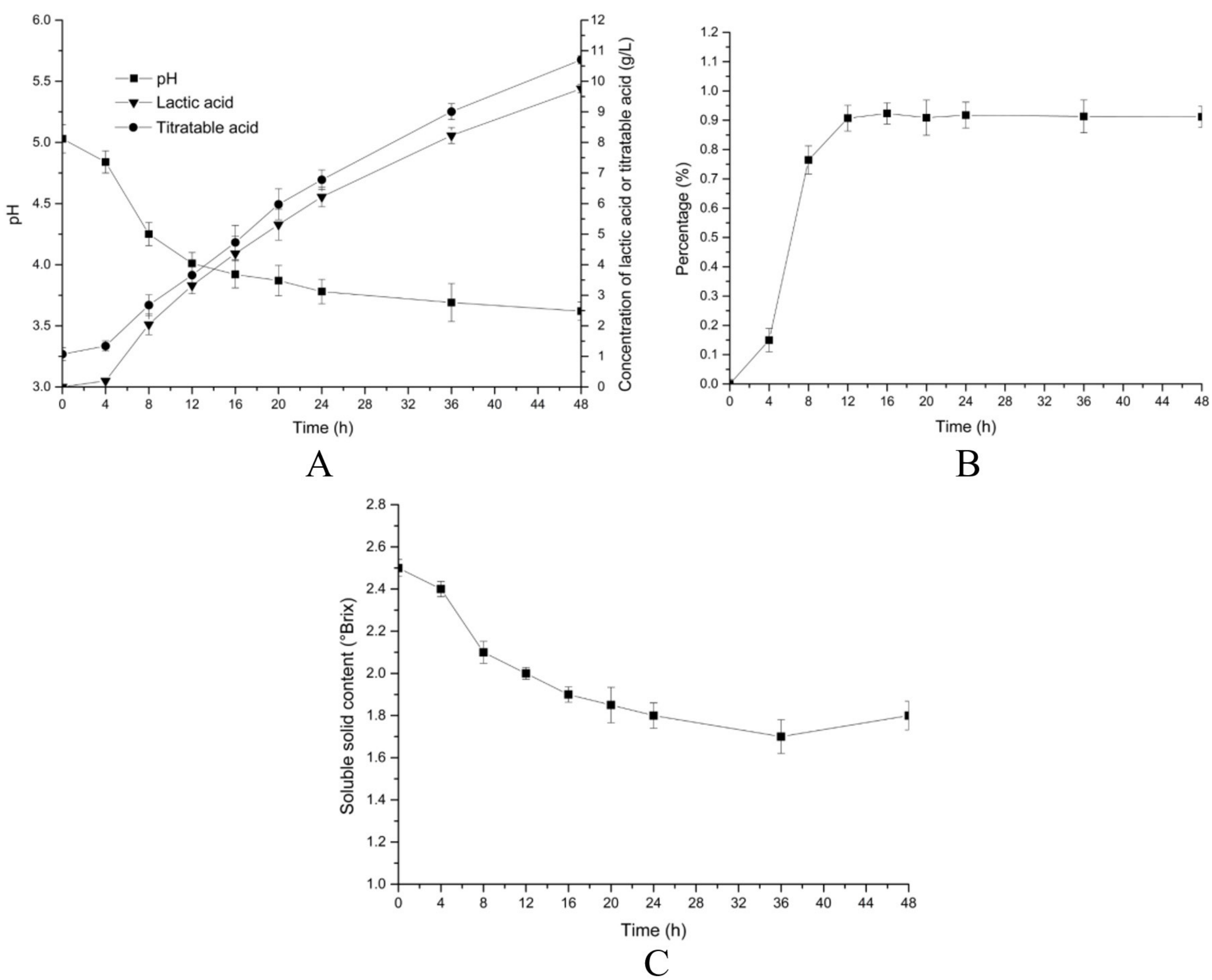

Figure 2. The chemical composition of fermented vegetable juice. (A) The changes of pH, lactic acid content and titratable acid content over time during fermentation; (B) The percentage of lactic acid in total acid; (C) Variation of soluble solids content.

inactivated, the phenomenon of decreased ascorbic acid in vegetable juice still occurs. According to reports, after heat treatment of lemon, the fermentation process had no significant effect on AA concentration (Hashemi et al., 2017). It was speculated that the reason for the decrease of AA was the high sensitivity of ascorbic acid to the natural storage environment (Wacher et al., 2010).

3.3 Results of principal component analysis of biochemical variables of Yam Juice (YJ) and Fermented Yam Juice (FYJ)

The optimal yeast fermentation conditions (28 °C, pH, natural) were selected to analyze the changes of biochemical components before and after yam fermentation. From Table 1, it can be seen that after 24 hours of yeast fermentation, the glucose content in yam juice decreased significantly, from 55.72 g/L in yam slurry to 0.0607 g/L. In a similar trend, the soluble solids decreased from 6.6 °Brix to 1.9 °Brix of fresh yam slurry. On the other hand, the acidity of fermented yam juice increased with the prolonged yeast fermentation time. The acidity of yam syrup increases with the course of fermented yeast, and the titratable acid rose from 7.14 g/L of yam juice to 9.51 g/L of fermented yam juice. The increasing trend in titratable acidity content was accompanied by a decrease in pH, that was, from pH 5.72 of yam juice to 4.88. Besides, the ethanol concentration in the fermentation juice increased from 0.16% vol to 2.86%vol.

3.4 Aroma component analysis

The chromatograms were presented in Figure 3. GC-MS analysis showed that four volatile components were detected in the yam juice: Decamethylcyclopentasiloxane, octamethyl-Cyclotetrasiloxane, Nonanal, and Decanal. After yeast fermentation, 34 species were detected in the yam juice, including esters, alkanes, and alcohols, ketones, aldehydes, acids, oximes, etc. Esters were the most abundant with 17 compounds, followed by 7 alkanes, then 5 alcohols and 5 ketones two sours, 1 aldehydes and 1 carcasses. Among all the volatile components, Ethyl 9-decenoate was the main aroma component of fermented yam juice with the highest content in all volatile components, which was 25.37%. Fifty-five volatile compounds were detected in vegetable juice and fermented vegetable juice by GC-MS. The volatile components in vegetable juices mainly included 10 aldehydes, 6 ketones, 5 aromatics, 8 olefins. In the fermented vegetable juice, the amount of aldehyde compounds decreased, and the content of esters, alkanes, and olefin compounds increased. Based on the formula in Supplementary Material Table 1, GC-MS analysis of the mixed fermentation broth revealed a total of 44 volatile components, including 17 ester compounds, 11 olefin compounds, 7 alcohol compounds, and 4 alkane compounds. There are three kinds of ketone compounds, one each of aldehydes and aromatic compounds. The main volatile components are 1-Butanol, 3-methyl-, and acetate, which are the most abundant in all aroma components. Ethanol was detected in the final mixed fermented vegetable juice assay. The ethanol content was 0.628%vol.

Table 1. Component contents of yam juice (YJ) and fermented yam juice (FYJ)[a].

Time (h)	0(YJ)	24 (FYJ)
Glucose content (g/L)	55.72 ± 2.4[b]	0.06 ± 0.0.2[b]
pH	5.72 ± 0.07[b]	4.88 ± 0.12[b]
Titratable acid content (In lactic acid)/(g/L)	7.14 ± 0.32[b]	9.51 ± 0.47[b]
Ethanol concentration (%vol)	0.16 ± 0.07[b]	2.86 ± 0.16[b]
Soluble solid (°Brix)	6.6 ± 0.4[b]	1.9 ± 0.3[b]

[a]Values are given as means ± standard deviation (SD) (n = 3); [b]Different letters in the same rows indicate statistical significance ($p < 0.05$).

3.5 Sensory evaluation

In the sensory test, the satisfaction survey report of the mixed vegetable juice product was satisfactory. Different proportions of fermented vegetable juice and fermented yam juice had differences in smell, taste and color appearance. The analysis results were shown in Table 2. The evaluation results showed that 80% FVJ+20% FYJ was superior to other groups in terms of odor and mouthfeel. Although the appearance of color was slightly lower than 100% fermented vegetable juice, the overall score was the highest. Based on sensory tests, the main point was that the product was too acid and the mouth-feel was too irritating followed by the odor as the product retains a rich aroma of lactic acid bacteria fermentation and yeast fermentation. As some fermented odor was still retained. Referring to the product optimization method (Kantachote et al., 2017), honey was added to the product to improve the sourness of the product. The facts in this study showed that the addition of 20% honey significantly enhances the sensory tests based on odor, flavor and overall acceptance, consistent with the findings (Kantachote et al., 2017). As cocktails need to be adjusted, more kinds of seasoning liquid will be used to develop mixed fermented vegetable juice beverages of various flavors in the future research.

Current research shows that it is possible to develop more types of fruit and vegetable juices or mixed fermentation beverages. The pursuit of health by consumers is the motivation for researchers to develop new probiotic beverages (Granato et al., 2010). Hayisamaae et al. (2014) developed a red seaweed fermented beverage using Lactobacillus plantarum, and Gardner et al. (2001) developed a novel vegetable juice beverage by lactic acid fermentation. Mousavi et al. (2011) used pomegranate juice for

Table 2. The results of sensory analysis.

Beverages	Sensory Attributes			
	Aroma	Taste	Color	Overall impression
80%FVJ+20%FYJ	8.9	8.4	8.5	8.7
80%FVJ+20%FYJ+10%honey	9	8.7	8.6	8.9
80%FVJ+20%FYJ+20%honey	9.2	9.3	8.6	9.2
80%FVJ+20%FYJ+10%water	8.6	8.5	8.2	8.4

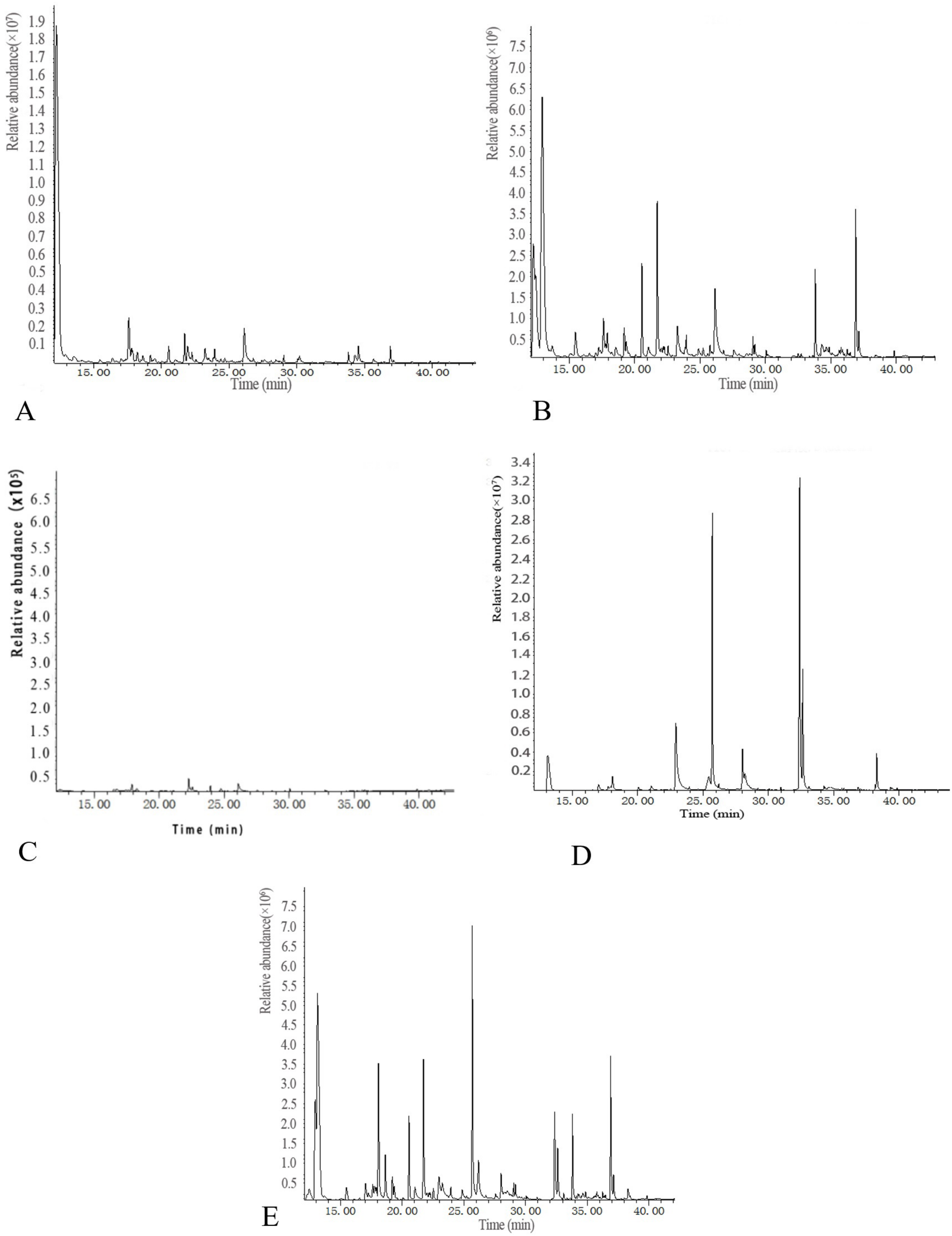

Figure 3. Gas Chromatography Mass Spectrometry Picture. (A) VJ of GC-MS; (B) FVJ of GC-MS; (C) YJ of GC-MS; (D) FYJ of GC-MS; (E) Mixed with FVJ and FYJ of GC-MS.

lactic acid fermentation to research fermented beverages. It has been reported that lactic acid bacteria can enter the digestive system and are beneficial to improving the system's microbial environment (Vamanu, 2015). Therefore, the development of probiotic-beverages using lactic acid bacteria is also a trend for maintaining good health.

3.6 Microbiological analysis

During the 28-day storage period at 4 °C, there was no other intestinal bacteria or mold in the fermented vegetable juice except for Lactobacillus plantarum. With the completion of fermentation, Lactobacillus fermentum become inactive due to the depletion of nutrients (sugar) and accompanied by increase of lactic acid. On the 28th day of preservation, the number of lactic acid bacteria was 7.34 ± 0.21 log CFU/mL. No microorganism other than Lactobacillus fermentum was detected in the mixed fermented vegetable juice sample, ensuring its sterility.

4 Conclusion

Vegetable juice could be used as an energy source for Lactobacillus plantarum, and yam juice could provide nutrition for yeast. The glucose content and ph value in the fermentation broth decreased. The ascorbic acid content in the fermented vegetable juice was reduced, and the lactic acid content was accumulated. After 48 hours of fermentation, the Lactobacillus plantarum cell count was 9.13log ± 0.19 log CFU/mL, and after storage at 4 °C for 28 days, they dropped to 7.34 log ± 0.21 log CFU/mL.

In addition, after the microbial fermentation, the types of aroma components in the yam pulp increased significantly, and the composition and proportion of the volatile components in the vegetable juice also changed. The identified esters, acids and other compounds provided unique taste and aroma for fermented drinks.

The blended beverages were approved by the panelists as a basis for the beverages of different fermented vegetable juices, demonstrating their potential for commercial production. If the fermented vegetable juice beverage is to be large-scale commercial produced, it was possible to experiment with the stability of biologically active substances, which had positive significance for the promotion of the products. Besides, employment opportunities could be provided for people who earned a living in the area where produced great crops of fruit and vegetables.

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Supplementary Material

Supplementary material accompanies this paper.

Table S1. Sensory rating of different proportions of FVJ and FYJ (n=50)

Table S2. Volatile components of yam juice and fermented yam juice in GC-MS

Table S3. Volatile components of vegetable juice and fermented vegetable juice in GC-MS

Table S4. Volatile components of mixed fermented yam juice and fermented vegetable juice in GC-MS

Figure S1. Flowchart for preparation of the mixed fermented vegetable juice

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