

## Effect of initial total soluble solids and pH on the quality of fermented beverage from green asparagus roots (*Asparagus officinalis* L.)

<sup>1,\*</sup>Giang, N.T.N., <sup>2</sup>Tan, N.D., <sup>3</sup>Khai, T.V. and <sup>3</sup>Tuyen, V.T.X.

<sup>1</sup>Experimental-practical Area, An Giang University, Vietnam National University Ho Chi Minh City, Vietnam

<sup>2</sup>Food Technology Department, Agriculture and Natural Resource Faculty, An Giang University, Vietnam National University Ho Chi Minh City, Vietnam

<sup>3</sup>Crop Science Department, Agriculture and Natural Resource Faculty, An Giang University, Vietnam National University Ho Chi Minh City, Vietnam

### Article history:

Received: 18 November 2022

Received in revised form: 16

January 2023

Accepted: 19 January 2023

Available Online: 20 June

2024

### Keywords:

Fermented beverage,

Green asparagus root,

Initial total soluble solids,

pH

### DOI:

[https://doi.org/10.26656/fr.2017.8\(3\).570](https://doi.org/10.26656/fr.2017.8(3).570)

### Abstract

Green asparagus (*Asparagus officinalis* L.) root was used as raw materials for the new fermented beverage because of its nutrition. With the goal of improving the value of green asparagus and contributing to the diversification of asparagus products; the fermented beverage (light alcoholic beverage) was the target of the research. The fermentation was conducted with 2 factors including initial total soluble solids (18-24°Bx) and pH (4.0-5.5). The results showed that the suitable conditions for fermenting the beverage from green asparagus root were 20°Bx and pH 4.5. The ethanol content, the contents of bioactive compounds (phenolic, flavonoid, tannin and saponin) and vitamin C (per 100 g of dry matter) of the fermented beverage from green asparagus were 5.0% v/v, 2.242 g tannic acid equivalent (TAE), 0.206 g quercetin equivalent (QE), 0.273 g TAE, 1.454 g saponin equivalent (SE) and 3.214 g, respectively.

## 1. Introduction

Asparagus (*Asparagus officinalis* L.) is well-known as the king of vegetables due to its health benefits and its bioactive compositions (Viera-Alcaide *et al.*, 2021), such as polysaccharides, polyphenols, anthocyanins, saponins, dietary fibre and oligosaccharides (Fuentes-Alventosa *et al.*, 2013), which exhibit anti-cancer, antitumor, antioxidant, immunomodulatory, hypoglycemic, anti-hypertensive and anti-epileptic effects (Guo *et al.*, 2020). However, during the harvest time, roots and rhizomes of this crop are usually dug out to cut and left on fields as the by-products (Viera-Alcaide *et al.*, 2021). This by-product is up to 30–40 thousand metric per ha of the plantation, and around 6.5 million thousand metric of asparagus roots are produced annually, which causes a great economic loss (Viera-Alcaide *et al.*, 2021). In addition, the contents of active components from the roots, especially the polysaccharides, account for the highest percentage in the bottom spears compared to other parts (Guo *et al.*, 2020) and fructans are the polysaccharides that are accumulated mostly in the asparagus root (Suzuki *et al.*, 2011; Witzel and Matros, 2020). Therefore, asparagus root is the potential raw material for research and development, particularly the creation of added-value products in order to utilize this

by-product.

Fermented beverages are complex solutions obtained from fermentation without distillation of thousands of organic compounds originating from the fruit, the yeast, and other microbial metabolism (Dias *et al.*, 2017). The fermented beverage has a mild alcohol content (less than 15%) and is considered a beneficial drink for women and the elderly due to its health benefits and the attractive flavors of fruits (Ngoc *et al.*, 2018). As with other types of fruits, the by-product from asparagus root contains a high amount of fructans, which is the main substance needed for fermentation and this material can be used to make fermented beverages like fruit wine, especially tropical fruits, such as apples (Xu *et al.*, 2007), strawberries (Santo *et al.*, 2012), pineapple (Thanh *et al.*, 2013; Thepkaew and Chimsri, 2013), sugarcane (Luciana *et al.*, 2014) and *Docynia indica* fruit (Hanh *et al.*, 2016). Fermented beverages' qualities, such as colors, flavor and present compounds, are characterized by the type of fruits and the fermentation processing. According to Ngoc *et al.* (2018) and Phong *et al.* (2021), the initial total soluble solids (TSS) and pH of the must are the crucial factors that affect the ethanol content and qualities of the fermented beverage. Moreover, the use of

\*Corresponding author.

Email: [ntngiang@agu.edu.vn](mailto:ntngiang@agu.edu.vn)

by-products from green asparagus root, with standardized methods and yeasts in the fermentation contributes to enhancing the content of desired bioactive substances in the new product. Therefore, the study aimed to determine the effect of initial total soluble solids (TSS) and pH on the quality of fermented beverage from green asparagus root including the total soluble solids, pH, ethanol content, the contents of bioactive compounds (phenolic, flavonoids, tannins and saponins) and vitamin C of the product.

## 2. Materials and methods

### 2.1 Materials

Green asparagus roots were harvested at My Thoi Ward, Long Xuyen City, An Giang province, Vietnam without damage and then transported to The Experimental-practical Area - An Giang University (Vietnam) within 1 hr. Green asparagus roots were washed and cut into  $1 \times 1 \text{ cm}^2$ .

*Saccharomyces cerevisiae* ( $3 \times 10^{10}$  CFU/g) in the form of powder was provided by Angel Yeast Co. Ltd (China). The density was followed by the information on the package of the manufacturer.

Saccharose was produced by Bien Hoa Company (Vietnam). Food-grade citric acid was a commercial product of Merck (Germany).

### 2.2 Experimental design

Five hundred grams of green asparagus root was blended with water at the ratio of 1:2.5 (w/v) for 5 mins and the pH of the mixture at 6.2 and was adjusted to the value of 4.0, 4.5, 5.0 and 5.5 with 10% citric acid (Jarun et al., 2008). The saccharose was added to get the mixture at 18, 20, 22 and 24°Bx from the total soluble solid content of the initial mixture at 1.8 (based on the results of Thuy et al. (2011), Udeagha et al. (2020) and Mi and Tien (2021)). The mixture was heated at 80°C for 10 mins to destroy harmful microorganisms and enzymes that cause browning reactions that affect the color of wine, and then cooled to room temperature (about 30°C) and 0.1% (w/w, compared to raw materials). *Saccharomyces cerevisiae* was added to the mixture for the fermentation process at room temperature for 10 days (Thuy et al., 2011). After fermentation, the solution was filtered and analyzed for the required parameters.

### 2.3 Analysis methods

#### 2.3.1 Determination of total soluble solid content and pH value

TSS and pH of samples were measured by using Atago hand-held refractometer (Japan) with 0-53°Bx of detection level range and pH meter (Hanna, USA),

respectively.

#### 2.3.2 Determination of the ethanol content

Ethanol content (% v/v) was measured by the distillation method (FSSAI, 2015). Approximately 200 mL of sample were put into a distillation flask (500 mL) containing 20-30 mL of saturated NaCl for the distillation to collect the distillate into a 200 mL volumetric flask and cooled the solutions to 20°C. Ethanol content (% v/v) was determined by an ethanol meter (PET 109, Atago, Japan).

#### 2.3.3 Determination of reducing sugar content

Reducing sugar content (g/kg of dry matter) was measured by the DNS method (Miller, 1959) with some modifications. A volume of 1 mL of sample was put in the test tube, and then 2 mL of reagent DNS was added. The blank tubes of standard glucose and samples were placed in boiling water for 10 mins. After that, 7 mL of distilled water was added to the tubes. This method is based on the oxidation of the C=O group by 3,5-Dinitrosalicylic acid from a yellow colour to orange-red in an alkaline medium. The solution was analyzed with absorption at 575 nm. The reducing sugar concentration was based on a standard glucose curve,  $y = 23885x + 0.126$  ( $R^2 = 0.9999$ ), where y is the absorbance, and x is the concentration of the solution in the tube.

#### 2.3.4 Determination of total acids content

The total acid content was measured by titration (Erinç et al., 2009). An acid-base titration is a quantitative analytical method to determine the acid concentration by precisely neutralizing it with a standard solution of a known base concentration (0.1 N NaOH). The concentration of total acids was calculated using Equation (1):

$$Ax = \frac{n \times V_1}{V_2 \times V_3}$$

Where n is the volume of 0.1 N NaOH to titrate (mL);  $V_1$  is volumetric flask capacity (mL);  $V_2$  is the volume of raw sample (mL), and  $V_3$  is the volume of diluted sample to titrate (mL).

#### 2.3.5 Determination of total phenolic content

Total phenolic content (mg TAE/kg of dry matter) was determined using the Folin-Ciocalteu reagent (Sumaiyah et al., 2015) with some modifications. About 150  $\mu\text{L}$  of the sample was mixed with 1200  $\mu\text{L}$  of distilled water and 450  $\mu\text{L}$  of 5% (w/v)  $\text{Na}_2\text{CO}_3$  in a test tube. The mixture was added to 0.1 mL of Folin-Ciocalteu reagent and left at room temperature for 90 mins to react. Phenolic in the extract reacts with Folin-Ciocalteu to form a blue complex in the alkaline

medium, the phosphomolybdenum complex. The concentration of total phenolics was calculated as equal to the standard tannic acid graph (TAE),  $y = 0.0021x + 0.0064$  ( $R^2 = 0.9999$ ), where  $y$  is the absorbance and  $x$  is the concentration of the solution in the tube.

### 2.3.6 Determination of total flavonoid content

This assay was performed using the aluminium chloride colorimetric method described by Sumaiyah *et al.* (2015) with some modifications. The principle is related to  $AlCl_3$  creating a stable acid complex with the C-4 keto groups and the hydroxyl C-3 or C-5 group of the flavon and flavonol. About 100  $\mu$ L of the sample was added with 1200  $\mu$ L of distilled water and 30  $\mu$ L of 5% (w/v)  $NaNO_2$ . After 5 mins, the mixture was mixed with 10% (w/v)  $AlCl_3 \cdot H_2O$  (60  $\mu$ L). Approximately 200  $\mu$ L of 1 M NaOH and 110  $\mu$ L of water were mixed into the solution. The solution was then measured at 510 nm. The total flavonoid concentration was calculated equally to the standard quercetin graph (QE),  $y = 8.2634x + 0.0182$  ( $R^2 = 0.9999$ ), where  $y$  is the absorbance, and  $x$  is the concentration of the solution in the tube.

### 2.3.7 Determination of tannin content

Tannin content was determined by the Folin-Denis method (Laitonjam *et al.*, 2013). Approximately 0.5 mL of sample was added 0.5 mL of distilled water, 0.5 mL of Folin-Denis and 2 mL of 20%  $Na_2CO_3$ . The mixture was shaken well, warmed in boiling water for 1 min and cooled to room temperature. The solution was measured at 700 nm. The concentration of tannin was calculated as equal to the standard tannic acid graph (TAE),  $y = 0.0098x + 0.0478$  ( $R^2 = 0.9999$ ), where  $y$  is the absorbance and  $x$  is the concentration of the solution in the tube.

### 2.3.8 Determination of saponin content

The saponin content was determined by the vanillin-sulfuric acid method (Le *et al.*, 2018). The basic principle related to the oxidation of triterpene saponins by sulfuric acid and vanillin produces a distinctive red-violet color. Approximately 0.25 mL of sample was taken in the test tube and added with 0.25 mL of 8% (w/v) vanillin in ethanol 96% and 2.5 mL of 72%  $H_2SO_4$  acid. The mixture was incubated at 60°C for 30 mins and then cooled to room temperature. The solution was measured at 560 nm. The concentration of saponin was calculated as equal to the standard saponin graph (SE),  $y = 0.1348x + 0.0075$  ( $R^2 = 0.9999$ ), where  $y$  is the absorbance and  $x$  is the concentration of the solution in the tube.

### 2.3.9 Determination of vitamin C

Vitamin C was performed using the 2,4-dinitrophenyl hydrazine colorimetric method described by Sharaa and Mussa (2019). Approximately 1 g of sample was taken in a 15 mL centrifuge tube and added with 5 mL of solution containing 3% meta-phosphoric acid (w/v) and 8% glacial acetic acid (v/v). The centrifuge tube was placed on the Reciprocating shaker (Stuart, UK) for 1 hr. 1 mL of solution after filtration was placed in a test tube and added with 0.5 mL of 3% bromine, 0.25 mL of 10% thiourea and 0.25 mL of 2,4-dinitrophenyl hydrazine. The mixture was incubated at 37°C for 3 hrs. After that, 10 mL of 85%  $H_2SO_4$  was added to the tube to form a red complex. The solution was cooled to room temperature and analyzed with an absorption of 521 nm. The concentration of vitamin C was calculated as equal to the standard ascorbic acid graph,  $y = 0.2253x + 0.0024$  ( $R^2 = 0.9999$ ), where  $y$  is the absorbance and  $x$  is the concentration of the solution in the tube.

### 2.3.10 Determination of colour

The colour of fermented beverage was measured using a Hunter L, a, b colourimeter (CR 400, Konica Minolta, Japan).

## 2.4 Data analysis

Data were collected and processed by STAGRAPHS Centurion 16.1 software for analysis variance (ANOVA), LSD test to conclude the difference between the average of experiments at 5% confidence ( $P = 0.05$ ). The response surface methodology (RSM) is based on the complete collection of experimental data, at the same time, determining the influence of the factors and reflected by the multivariate equation. Microsoft Excel software was used for calculating and graphing.

## 3. Results and discussion

### 3.1 Effect of initial total soluble solids and pH values of green asparagus roots on ethanol content and physicochemical parameters of fermented beverage quality

The effect of initial TSS and pH values on ethanol content and physicochemical parameters are shown in Figure 1 and Table 1.

The results in Table 1 showed that the initial TSS and pH of the solution affected the ethanol content, pH, TSS and color (through L, a, b values) of the fermented beverage at 1% significantly different levels. The content of ethanol increased with the TSS that ranged from 18 to 20°Bx, however, tended to decrease when continuing to increase the initial TSS of the green asparagus roots must

Table 1. The effect of the initial TSS and pH of green asparagus roots on the physicochemical compositions of fermented beverages.

| Treatment | Before fermentation |            |                    | After fermentation   |                      |                       |                       |                     |
|-----------|---------------------|------------|--------------------|----------------------|----------------------|-----------------------|-----------------------|---------------------|
|           | Initial TSS (°Bx)   | Initial pH | Ethanol (% v/v)    | pH                   | TSS (°Bx)            | L                     | a                     | b                   |
| 1         | 18                  | 4          | 3.75 <sup>*c</sup> | 3.21 <sup>fg</sup>   | 13.325 <sup>h</sup>  | 41.25 <sup>cde</sup>  | -3.44 <sup>bcd</sup>  | 4.50 <sup>abc</sup> |
| 2         | 18                  | 4.5        | 5.0 <sup>a</sup>   | 3.1225 <sup>j</sup>  | 12.425 <sup>i</sup>  | 42.1425 <sup>ab</sup> | -3.50 <sup>cd</sup>   | 4.39 <sup>bcd</sup> |
| 3         | 18                  | 5          | 5.0 <sup>a</sup>   | 3.275 <sup>b</sup>   | 11.725 <sup>j</sup>  | 41.26 <sup>cde</sup>  | -3.07 <sup>ab</sup>   | 4.15 <sup>de</sup>  |
| 4         | 18                  | 5.5        | 4.375 <sup>c</sup> | 3.2225 <sup>de</sup> | 11.225 <sup>k</sup>  | 41.63 <sup>bcd</sup>  | -3.21 <sup>abcd</sup> | 4.28 <sup>cde</sup> |
| 5         | 20                  | 4          | 4.625 <sup>b</sup> | 3.0125 <sup>m</sup>  | 14.525 <sup>g</sup>  | 41.87 <sup>abc</sup>  | -3.43 <sup>bcd</sup>  | 4.58 <sup>ab</sup>  |
| 6         | 20                  | 4.5        | 5.0 <sup>a</sup>   | 3.33 <sup>a</sup>    | 14.75 <sup>g</sup>   | 41.345 <sup>cde</sup> | -3.40 <sup>bcd</sup>  | 4.39 <sup>bcd</sup> |
| 7         | 20                  | 5          | 5.0 <sup>a</sup>   | 3.2325 <sup>d</sup>  | 19.725 <sup>ab</sup> | 41.08 <sup>de</sup>   | -3.17 <sup>abc</sup>  | 4.44 <sup>bc</sup>  |
| 8         | 20                  | 5.5        | 4.875 <sup>a</sup> | 3.2125 <sup>ef</sup> | 18.8 <sup>d</sup>    | 41.37 <sup>cde</sup>  | -3.1 <sup>ab</sup>    | 4.085 <sup>e</sup>  |
| 9         | 22                  | 4          | 4.0 <sup>d</sup>   | 3.115 <sup>j</sup>   | 16.95 <sup>f</sup>   | 42.3925 <sup>a</sup>  | -3.5 <sup>cd</sup>    | 4.73 <sup>a</sup>   |
| 10        | 22                  | 4.5        | 5.0 <sup>a</sup>   | 3.195 <sup>h</sup>   | 16.9 <sup>f</sup>    | 40.63 <sup>ef</sup>   | -3.14 <sup>abc</sup>  | 4.21 <sup>cde</sup> |
| 11        | 22                  | 5          | 5.0 <sup>a</sup>   | 3.0825 <sup>l</sup>  | 17.775 <sup>e</sup>  | 41.20 <sup>cde</sup>  | -3.16 <sup>abc</sup>  | 4.04 <sup>e</sup>   |
| 12        | 22                  | 5.5        | 4.625 <sup>b</sup> | 3.1 <sup>k</sup>     | 17.525 <sup>e</sup>  | 40.95 <sup>def</sup>  | -3.09 <sup>ab</sup>   | 4.40 <sup>bcd</sup> |
| 13        | 24                  | 4          | 3.0 <sup>f</sup>   | 3.2625 <sup>c</sup>  | 18.6 <sup>d</sup>    | 41.58 <sup>bcd</sup>  | -3.335 <sup>bcd</sup> | 4.66 <sup>ab</sup>  |
| 14        | 24                  | 4.5        | 4.875 <sup>a</sup> | 3.2 <sup>gh</sup>    | 19.25 <sup>c</sup>   | 40.98 <sup>def</sup>  | -3.365 <sup>bcd</sup> | 4.48 <sup>abc</sup> |
| 15        | 24                  | 5          | 4.875 <sup>a</sup> | 3.1525 <sup>i</sup>  | 19.825 <sup>a</sup>  | 41.01 <sup>de</sup>   | -3.58 <sup>d</sup>    | 4.15 <sup>de</sup>  |
| 16        | 24                  | 5.5        | 4.0 <sup>d</sup>   | 3.2225 <sup>de</sup> | 19.525 <sup>bc</sup> | 40.245 <sup>f</sup>   | -2.845 <sup>a</sup>   | 1.00 <sup>e</sup>   |

Level of significance

\*\* \*\* \*\* \*\* \*\*

Values are presented as means of triplicate testing. Values with different superscripts in each column are statistically significantly different. \*\* Statistically significant at 99%.

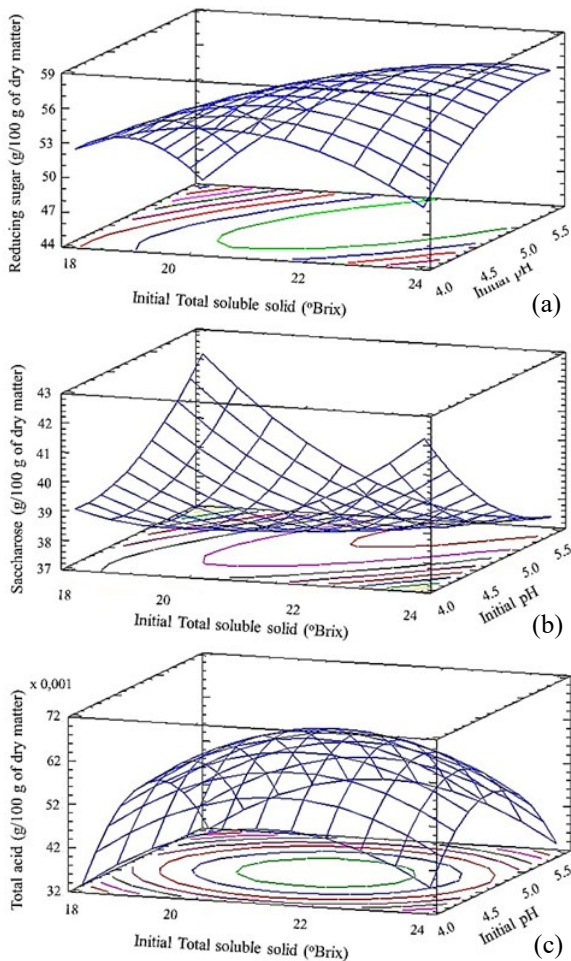


Figure 1. The response surface plots of the initial TSS and pH to the chemical compositions of fermented beverage from green asparagus roots (a) reducing sugar, (b) saccharose and (c) total acid.

( $p < 0.05$ ). Besides, the ethanol content gained the highest at the initial pH of 4.5 and 5.0, then gradually decreased with the increase in the pH value of the green asparagus roots. In parallel, the results in Figure 1a also showed that the reducing sugar content of the fermented beverage increased to an optimal value, then gradually decreased with increasing TSS and pH values. In contrast, sucrose decreased with increasing initial pH (Figure 2b). The content of TSS has a great influence on the growth of yeast and the rate of fermentation, which is mainly sugar. If it is too high, it will reduce the fermentation activity of yeast. Yeast needs carbohydrates for growth and metabolism. Sugar is an essential substrate for fermentation and greatly affects fermentation performance. *Saccharomyces cerevisiae* can convert sugars into ethanol (Fleet, 2003) and the ethanol content is high or low depending on the sugar content in the fermentation (Attri, 2009; Ton *et al.*, 2010). Therefore, the initial TSS must be suitable for yeast to grow and develop. When the initial sugar content of the must is low, yeast will lack a carbon source to increase biomass and compete for nutrients, resulting in low ethanol content. However, if the sugar content in the must is too high, it will increase the osmotic pressure and cause an imbalance in yeast's physiological and metabolic state (Attri, 2009). Besides, pH is one of the important factors that profoundly affect the fermentation process. Too low or too high pH will change the protein structure of many enzymes present in

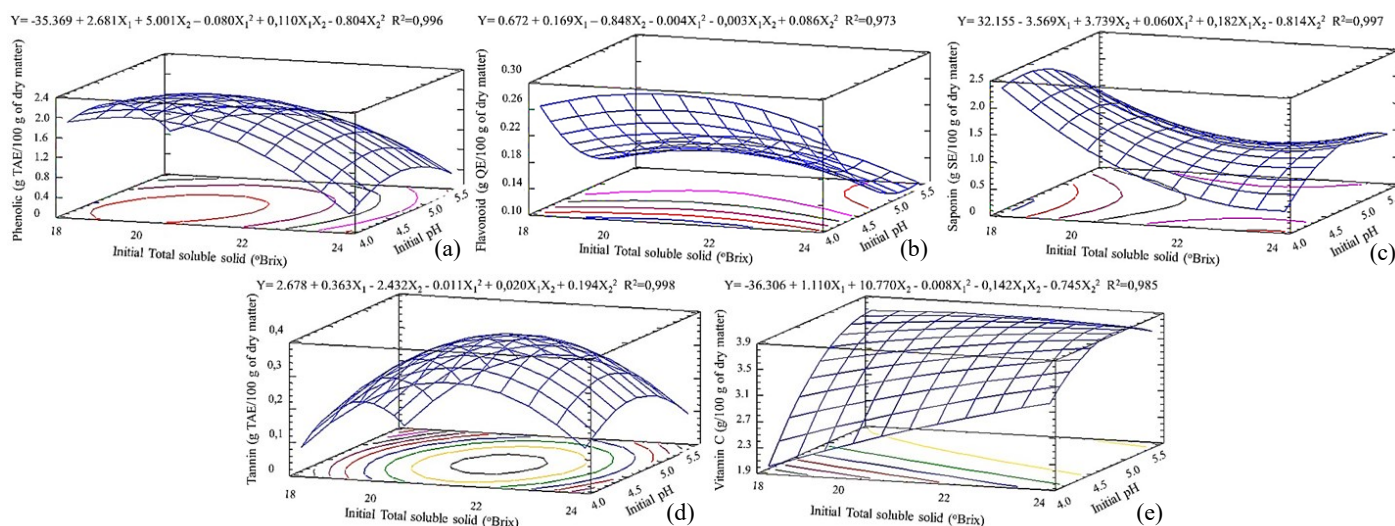


Figure 2. The response surface and contour plots showing the effect of the initial TSS and pH on (a) phenolic, (b) flavonoid, (c) saponin, (d) tannin and (e) vitamin C of fermented beverage from green asparagus roots.

the raw materials directly involved in the juice fermentation and reduce the enzyme's ability to activate (Pamulha and Loureiro-Dias, 1989; Ton *et al.*, 2008).

The TSS of the product after fermentation decreased in all treatments and it was lowest when the must was adjusted with the initial TSS and pH at 18°Bx and pH5.5. The reducing sugar content was also the lowest in this treatment. This reduction may be due to the more efficient fermentation of *S. cerevisiae* compared with the other treatments (Owusu *et al.*, 2012). According to Abrol *et al.* (2015), the trend of increasing ethanol or decreasing TSS during fermentation is inevitable.

With the initial pH adjustment of the asparagus root's must from 4.0 to 5.5, after the fermentation, the pH of the fermented beverage decreased ranging 3.30-3.01. According to Fleet (2003), the pH of the fermented solution can be reduced due to the activity of yeast in anaerobic fermentation, producing CO<sub>2</sub> and some organic acids, reducing the pH of the fermented solution. In addition, in the same initial TSS or initial pH, the pH of the fermented solution decreased to a value and then increased slowly with the increasing of the influencing factors (Figure 1c). At the same time, the total acid content of the fermented beverage was inversely proportional to the pH values, increased to a value and then decreased gradually with the increase of initial TSS or the initial pH of the must. The pH and total acidity are closely related to and quality parameters of fermented beverages (Jackson, 2008). The pH of fermented beverages can increase due to acid precipitation or yeast metabolism. The initial pH of the juice must be greater than 3.4 to affect fermentation positively. Prior studies have noted the importance of β-glucosidase activity produced in the hydrolysis of monoterpenes glucosides presented in the fruit juice during the fermentation by the yeast, especially the *Saccharomyces* strain. The activity of this enzyme contributes to affecting the aromatic

characteristics of fermented beverages due to the release of volatile acids and reducing the pH of the solution (Ugliano, 2009; Owusu *et al.*, 2012; Lin *et al.*, 2022). β-glucosidase activity is very susceptible to low pH but induced in the presence of high ethanol content (Brizuela *et al.*, 2021). Moreover, a lower fermented pH (<3.8) will improve the stability of the wine, inhibit the growth of yeast and also create good conditions for sugar fermentation (Ribéreau-Gayon *et al.*, 2006).

The initial TSS and pH of the green asparagus roots must also influence the color of the fermented beverage (through L, a, b values). The more positive the L value, the more negative the a and b values, the brighter the color of the beverage. The results showed that the initial TSS was 18 and 20°Bx; at pH 4.0 and pH 4.5 (p>0.05), the fermented beverage had a brighter green color than the rest of the samples.

### 3.2 Effect of the initial TSS and pH of green asparagus roots on the bioactive compounds of fermented beverage

The response surface models demonstrated the influence of the initial TSS and pH of the must from green asparagus root on the content of bioactive compounds (phenolic, flavonoids, tannins and saponins) and vitamin C of the fermented beverage formulated (Figure 2).

The results showed that the initial TSS and pH significantly affected the bioactive compounds of the fermented beverage from green asparagus roots (p<0.01). The contents of phenolic, flavonoid, and tannin increased to an optimal value, then gradually decreased and gained the highest when the initial TSS was 20°Bx. The saponin content was inversely proportional to the increase in the initial TSS. In contrast, the vitamin C content increased with the increase of the initial TSS.

The results also showed that when the phenolic,

saponin and tannin contents increased to an optimal value and then gradually decreased with increasing the initial pH of the must. At pH 5.0, the contents of phenolic and saponin were highest. However, vitamin C content had the highest value at pH 5.0. In contrast, the flavonoid content tended to be the opposite and declined with the higher initial pH of must.

Phenolic, flavonoids and tannins are the main factors determining fermented beverage quality. These compounds play an important role in fermented beverages' organoleptic characteristics, such as color, taste, preference, etc. (Morata *et al.*, 2016; Perez-Jiménez *et al.*, 2019). Phenolic includes hydroxycinnamic acid and hydroxybenzoic acid and contributes to the bitterness of fermented beverages (Zhang *et al.*, 2021). Flavonoids are formed in plants from the aromatic amino acids phenylalanine and tyrosine (Iwuozor, 2019). Tannins are important astringents for fermented beverage's organoleptic properties (Zhang *et al.*, 2021). Saponins are glycosides that bind to carbohydrates and contribute to bitterness and foaming (Iwuozor, 2019). These compounds in fermented beverages are mainly from raw materials or are generated during fermentation with microbial activities (Lingxi and Bashan, 2019; Morata *et al.*, 2020). The fermentation method affects the content of bioactive compounds (Merwin *et al.*, 2008). Besides, fermentation can change the structure of compounds through enzymatic action, hydrolysis, condensation, polymerization, etc. (Tatdao *et al.*, 2014). Tannins can interact with mannoproteins of yeast cell walls to form complex structures through polymerization (Karas *et al.*, 2019). In addition, bioactive compounds can diffuse across the cytoplasmic membrane of dead or inactivated yeast to interact with cytoplasmic components, mainly yeast proteins (Mekoue Nguela *et al.*, 2015). In addition, hydrolytic enzymes derived from raw materials or microorganisms can promote the hydrolysis of biologically active substances in wine (Vilena *et al.*, 2007). Furthermore, the reduction in phenolic compounds during fermentation is due to esterification with methanol and ethanol, resulting from yeast metabolism (Monagas *et al.*, 2005).

In addition, there was a clear trend, the higher the L value and the smaller the a value so the product had a brighter and greener color. The results in Table 1 also showed that the fermented beverage from green asparagus root was bright green in the sample with initial TSS of 18 and 20°Bx and initial pH of 4 and 4.5 ( $p > 0.05$ ). At the same time, the results of preliminary sensory evaluation of the beverage from green asparagus root (data not given here) showed that the fermented beverage product has a harmonious aroma, sweet and

sour taste, no bitter taste and high preference in samples with initial TSS and pH 20°Bx and 4.5, respectively.

Thus, initial TSS and pH is 20°Bx and 4.5 were also used to ferment wine products from some fruits such as jamun fruit (Chaudhary *et al.*, 2017), jackfruit wine (Ngoc *et al.*, 2018), three-leaf cayratia (Tien *et al.*, 2019; Linh, 2021).

The analysis results indicated in Figure 2 showed that the  $R^2$  of the predictive models is quite high ( $R^2 > 0.97$ ), they can be used to predict the effect of initial TSS and pH on the bioactive compounds of fermented beverage from green asparagus root (Guan and Yao, 2008).

#### 4. Conclusion

Green asparagus root was considered a potential raw material for the production of fermented beverages with yeast *S. cerevisiae*. In order to ensure and create a good quality product, the fermentation process was recommended to be conducted at the initial TSS of 20°Bx and pH 4.5. The fermented beverage had a high content of biologically active substances and ethanol content reached 5.0% v/v.

#### Conflict of interest

The authors declare no conflict of interest.

#### Acknowledgments

This research was funded by Vietnam National University Ho Chi Minh City (VNU-HCM) under grant number "C2022-16-12".

#### References

- Abrol, G.S., Sharma, K.D. and Kumar, S. (2015). Effect of initial total soluble solids on physico-chemical, antioxidant and sensory properties of mulberry (*Morus Indica* L.) wine. *Journal on Processing and Energy in Agriculture*, 19(5), 228-232.
- Attri, B.L. (2009). Effect of initial sugar concentration on physico-chemical characteristics and sensory quality of cashew apple wine. *Natural Product Radiances*, 8(4), 374-379.
- Brizuela, A.S., Arnez-Arancibia, M., Semorile, L., Pozo-Bayón, M.Á, Bravo-Ferrada, B.M. and Tymczyszyn, E.E. (2021).  $\beta$ -Glucosidase Activity of *Lactiplantibacillus plantarum* UNQLp 11 in different malolactic fermentations conditions: effect of pH and ethanol content. *Fermentation*, 7, 22. <https://doi.org/10.3390/fermentation7010022>
- Chaudhary, C., Khatak, A., Devi, R., Rai, D. and Yadav,

- B.S. (2017). Study of fermentation variables for the preparation of wine from jamun fruit. *Journal Of Pure and Applied Microbiology*, 11(3), 1623-1631. <https://doi.org/10.22207/JPAM.11.3.50>
- Dias, D., Duarte, W. and Schwan, R. (2017). Methods of Evaluation of Fruit Wines. In Kosseva, M.R., Joshi, V.K. and Panesar, P.S. (Eds.) *Science and Technology of Fruit Wine Production*, p. 227-252. USA: Academic Press. <https://doi.org/10.1016/B978-0-12-800850-8.00005-3>
- Erinç, H., Tekin, A. and Özcan, M.M. (2009). Determination of fatty, tocopherol and phytosterol contents of the oils of various poppy (*Papaver somniferum L.*) seeds. *Grasas Y Aceites*, 60(4), 375-381. <https://doi.org/10.3989/gya.129508>
- Fleet, G.H. (2003). Yeast interactions and wine flavour. *International Journal of Food Microbiology*, 86(1), 11-22. [https://doi.org/10.1016/S0168-1605\(03\)00245-9](https://doi.org/10.1016/S0168-1605(03)00245-9)
- Food Safety and Standard Authority of India (FSSAI). (2015). *Analysis of foods: Alcoholic beverages*. New Delhi, India: Ministry of health and family welfare, Government of India.
- Fuentes-Alventosa, J.M., Jaramillo-Carmona, S., Rodríguez-Gutiérrez, G., Rodríguez-Arcos, R.J., Fernández-Bolaños, J., Guillén-Bejarano, R., Espejo-Calvo, J. and Jiménez-Araujo, A. (2013). Effect of the extraction method on phytochemical composition and antioxidant activity of high dietary fibre powders obtained from asparagus by-products. *Food Chemistry*, 2(15), 484-490. <https://doi.org/10.1016/j.foodchem.2009.02.074>
- Guan, X. and Yao, H. (2008). Optimization of viscozyme L assisted extraction of oat bran protein using response surface methodology. *Food Chemistry*, 106(1), 345-351. <https://doi.org/10.1016/j.foodchem.2007.05.041>
- Guo, Q., Wang, N., Liu, H., Li, Z., Lu, L. and Wang, C. (2020). The bioactive compounds and biological functions of *Asparagus officinalis* L. - A review. *Journal of Functional Foods*, 65, 103727. <https://doi.org/10.1016/j.jff.2019.103727>
- Hanh, N.Đ., Hang, H.T.L., Mai, H.T.T. and Loi N.V. (2016). Study on use of *Saccharomyces cerevisiae* in cider making from *Docynia indica* fruit. *Vietnam Journal of Agriculture Sciences*, 8(69), 89-93.
- Iwuozor, K.O. (2019). Qualitative and Quantitative Determination of Anti-Nutritional Factors of Five Wine Samples. *Advanced Journal of Chemistry-Section A*, 2(2), 136-146. <https://doi.org/10.29088/SAMI/AJCA.2019.2.136146>
- Jackson, S.R. (2008). *Wine Science: Principles and Applications*. 3<sup>rd</sup> ed. Elsevier Inc. London.
- Jarun, C., Chuichuleherm, S., Chisti, Y. and Srinophakun, P. (2008). Protease production by *Aspergillus oryzae* in solid-state fermentation using agroindustrial substrates. *Journal of Chemical Technology and Biotechnology*, 83(7), 1012-1018. <https://doi.org/10.1002/jctb.1907>
- Karas, B.J., Moreau, N.G., Deerinck, T.J., Gibson, D.G., Venter, J.C., Smith, H.O. and Glass, J.I. (2019). Direct Transfer of a *Mycoplasma mycoides* Genome to Yeast Is Enhanced by Removal of the Mycoides Glycerol Uptake Factor Gene *glpF*. *ACS Synthetic Biology*, 8(2), 239-244. <https://doi.org/10.1021/acssynbio.8b00449>
- Laitonjam, W.S, Yumnam, R., Asem, S.D. and Wangkheirakpam, S.D. (2013). Evaluative and comparative study of biochemical, trace elements and antioxidant activity of *Phlogacanthus pubinervius* T. Anderson and *Phlocanthus jenkinicii* C.B. Clarke leaves. *Indian Journal of Natural Products and Resources*, 4(1), 67-72.
- Lin, X., Tang, X., Han, X., He, X. Han, N. and Sun, Y. (2022). Effect of metschnikowia pulcherrima on *Saccharomyces cerevisiae* PDH by-pass in mixed fermentation with varied sugar concentrations of synthetic grape juice and inoculation ratios. *Fermentation*, 8, 480. <https://doi.org/10.3390/fermentation8100480>
- Lingxi, L. and Baoshan, S. (2019). Grape and wine polymeric polyphenols: Their importance in enology. *Critical Reviews in Food Science and Nutrition*, 59(4), 563-579. <https://doi.org/10.1080/10408398.2017.1381071>
- Linh, P.T.K. (2021). Impact of changes in pH levels on the fermentation of watermelon juice. *Industry and Trade Magazine*, 14, 477-481.
- Luciana, S.R. Whasley, F.D., Disney, R.D. and Rosane, F.S. (2014). Fermented sugarcane and pineapple beverage produced using *Saccharomyces cerevisiae* and non-*Saccharomyces* yeast. *Journal of Institute of Brewing and Distilling*, 121(2), 262-272. <https://doi.org/10.1002/jib.218>
- Mekoue Nguela, J., Sieczkowski, N., Roi, S. and Vernhet, A. (2015). Sorption of grape proanthocyanidins and wine polyphenols by yeasts, inactivated yeasts, and yeast cell walls. *Journal of Agriculture and Food Chemistry*, 63, 660-670. <https://doi.org/10.1021/jf504494m>
- Merwin, I.A., Valois, S. and Padilla-Zakour, O.I. (2008). Chapter 6. Cider apples and cider-making techniques in Europe and North America. In Janick, J. (Ed.) *Horticultural Reviews*. Vol. 34, p. 365-415. United

- Kingdom: Wiley Online. <https://doi.org/10.1002/9780470380147.ch6>
- Mi, H.T.N. and Tien, D.T.K. (2021). Fermentation of pitaya (*Selenicereus undatus*) using *Saccharomyces cerevisiae* RV100. *TNU Journal of Science and Technology*, 226(14), 137-145. <https://doi.org/10.34238/tnu-jst.4795>
- Miller, G.L. (1959). Use of dinitrosalicylic acid reagent for determination of reducing sugar. *Analytical Chemistry*, 31(3), 426-428. <https://doi.org/10.1021/ac60147a030>
- Monagas, M., Suárez, R. and Gómez-Cordoves, C. (2005). Updated knowledge about the presence of phenolic compounds in wine. *Critical Reviews in Food Science and Nutrition*, 45(2), 85-118. <https://doi.org/10.1080/10408690490911710>
- Morata, A., Escott, C., Bañuelos, M.A., Loira, I., del Fresno, J.M., González, C. and Suárez-Lepe, J.A. (2020). Contribution of non-*Saccharomyces* yeasts to wine freshness. A review. *Biomolecules*, 10(1), 34. <https://doi.org/10.3390/biom10010034>
- Morata, A., Loira, I. and Suárez Lepe, J. (2016). Influence of yeasts in wine colour. In Morata, A. and Loira, I. (Eds). *Grape and wine biotechnology*, p. 285-305. InTech Open E-Book. <https://doi.org/10.5772/65055>
- Ngoc, T.T.A., Ngoc, B.T.A., Ngoc, N.T.M. and Quang, N.M. (2018). Effect of pH and total soluble solids on the fermentation process of the rags of Thai jackfruit cultivar (*Artocarpus heterophyllus*). *Can Tho University Journal of Science*, 54, 211-218. <https://doi.org/10.22144/ctu.jsi.2018.084> [In Vietnamese].
- Owusu, J., Ma, H., Wang, Z. and He, R. (2012). The influence of pH on quality of tomato (*Lycopersicon esculentum* Mill) wine. *International Journal of Advanced Biotechnology and Research*, 3(3), 625-634.
- Pamulha, M.E. and Louriero-Dias, M.C. (1989). Combined effect of acetic acid, pH and ethanol on intracellular pH of fermenting yeast. *Applied Microbiology and Biotechnology*, 31(5), 547-550. <https://doi.org/10.1007/BF00270792>
- Perez-Jiménez, M., Chaya, C., and Pozo-Bayón, M.Á. (2019). Individual differences and effect of phenolic compounds in the immediate and prolonged in-mouth aroma release and retronasal aroma intensity during wine tasting. *Food Chemistry*, 285, 147-155. <https://doi.org/10.1016/j.foodchem.2019.01.152>
- Phong, H.X., Kiet, H.V., Hung, L.T. Ai, T.K and Chau, L.M. (2021). Optimization of fermentation conditions in wine production from soursop (*Annona muricata* L.) using *Saccharomyces cerevisiae* FBY015. *TNU Journal of Science and Technology*, 226(5), 95-103.
- Ribéreau-Gayon, P., Dubourdieu, D., Donèche, B. and Lonvaud, A. (Eds.) (2006). *Handbook of Enology, Vol. 1. The Microbiology of Wine and Vinifications*. 2<sup>nd</sup> ed. United Kingdom: John Wiley & Sons, Ltd.
- Santo, D.E., Galego, L., Gonçalves, T. and Quintas, C. (2012) Yeast diversity in the Mediterranean strawberry tree (*Arbutus unedo* L.) fruits' fermentations. *Food Research International*, 47(1), 45-50. <https://doi.org/10.1016/j.foodres.2012.01.009>
- Sharaa, I.E.S. and Mussa, S.B. (2019). Determination of vitamin C (Ascorbic acid) contents in vegetable samples by UV-Spectrophotometry and redox titration methods and estimation of effect of time, cooking and frozen on ascorbic acid contents. *International Journal of Progressive Sciences and Technologies*, 15, 281-293.
- Sumaiyah, Masfria and Dalimunthe (2015). Determination of total phenolic content, total flavonoid content, and antimutagenic activity of ethanol extract nanoparticles of *Raphidophora pinnata* (L.F) Schott. Leaves. *Rasayan Journal of Chemistry*, 11(2), 505-510. <https://doi.org/10.31788/RJC.2018.1122068>
- Suzuki, T., Maeda, T., Nomura, S., Suzuki, M., Grant, G. and Sporns, P. (2011). Rapid analysis of fructans and comparison of fructans profiles in several different types of asparagus storage roots using MALDI-TOF MS. *Journal of Horticulture Science and Biotechnology*, 86(3), 210-216. <https://doi.org/10.1080/14620316.2011.11512749>
- Tatdao, P., Norrasat, S. and Tiwawan, S. (2014). Physico-chemical and sensory properties of musts and wines from *Melodorum fruticosum* Lour. *International Food Research Journal*, 21(1), 39-43.
- Thanh, N.V., Thuy, N.M, Que, T.T., Tuyen, N.T.M., Cuong, N.P. and Toan, T.H. (2013). Using isolated and purified yeast for pineapple (Cau Duc, Hau Giang) wine processing. *Can Tho University Journal of Science*, 27, 56-63. [In Vietnamese].
- Thepkaew, N. and Chimsri, N. (2013) Fermentation of pineapple juice using wine yeasts: Kinetics and characteristics. *Asian Journal of Food and Agro-Industry*, 6, 1-10.
- Thuy, N.M., Tuyen, N.T.M, Cuong, N.P., Thanh, D.K., Boi, L.V., Chinh, H.T. and Nhan, P.T. (2011). Effect of isolated yeast cell number, total soluble solid and pH value to palm wine quality. *Can Tho University Journal of Science*, 19b, 209-218. [In Vietnamese].
- Tien, Đ.T.K., Mi, H.T.N., Nghi, L.H. and Phong, H.X.

- (2019). Evaluation of total polyphenol and antioxidant capacity in wine fermentation of three-leaf cayratia from Ca Mau province using *Saccharomyces cerevisiae* CM3.2. *Can Tho University Journal of Science*, 2, 285-291. <https://doi.org/10.22144/ctu.jsi.2019.072> [In Vietnamese].
- Ton, N.M.N., Le, N.L., Nguyen, T.H.L. and Le, V.V.M. (2008). Effect of initial pH value of must on kinetics of wine fermentation, using yeast immobilized in calcium alginate gel. In Le, D.D. (Ed.). Proceedings of the 4<sup>th</sup> National Scientific Conference on Biochemistry and Molecular Biology for Agriculture, Biology, Medicine and Food industry, p. 383-386. Hanoi, Vietnam.
- Ton, N.M.N., Nguyen, M.D., Pham, T.T.H. and Le, V.V.M. (2010). Influence of initial pH and sulfur dioxide content in must on wine fermentation by immobilized yeast in bacteria cellulose. *International Food Research Journal*, 17, 743-749.
- Udeagha, E.C., Ishiwu, C.N., Obiora, C.U. and Iwouno, J.O. (2020). Effects of yeast concentration and total soluble solids on the quality of wine produced from pineapple. *Current Journal of Applied Science and Technology*, 39(30), 28-42. <https://doi.org/10.9734/cjast/2020/v39i3030968>
- Ugliano, M. (2009). Enzymes in winemaking. In Moreno-Arribas, M.V. and Polo, M.C. (Eds.). *Wine Chemistry and Biochemistry*, p. 103-126. Australia: Springer Science+Business Media, LLC. [https://doi.org/10.1007/978-0-387-74118-5\\_6](https://doi.org/10.1007/978-0-387-74118-5_6)
- Viera-Alcaide, I., Hamdi, A., Guillén-Bejarano, R., Rodríguez-Arcos, R., Esperjo-Calvo, J.A. and Jiménez-Araujo, A. (2022). Asparagus roots: from an agricultural by-product to a valuable source of fructans. *Foods*, 11(5), 652. <https://doi.org/10.3390/foods11050652>
- Viera-Alcaide, I., Hamdi, A., Guillén-Bejarano, R., Rodríguez-Arcos, R., Espejo-Calvo, J.A. and Jiménez-Araujo, A. (2022). Asparagus Roots: From an Agricultural By-Product to a Valuable Source of Fructans. *Foods*, 11(5), 652. <https://doi.org/10.3390/foods11050652>
- Vilena, M., Ubeda, I.J.F. and Briones, P.A.I. (2007).  $\beta$ -glucosidase activity in wine yeasts: application in enology. *Enzyme and Microbial Technology*, 40(3), 420-425. <https://doi.org/10.1016/j.enzmictec.2006.07.013>
- Witzel, K. and Matros, A. (2020). Fructans are differentially distributed in root tissues of asparagus. *Cells*, 9(9), 1943. <https://doi.org/10.3390/cells9091943>
- Xu, Y., Fan, W. and Qian, M.C. (2007). Characterization of aroma compounds in apple cider using solvent-assisted flavor evaporation and headspace solid-phase microextraction. *Journal of Agriculture and Food Chemistry*, 55, 3051-3057. <https://doi.org/10.1021/jf0631732>
- Zhang, P., Ma, W., Meng, Y., Zhang, Y., Jin, G. and Fang, Z. (2021). Wine phenolic profile altered by yeast: Mechanisms and influences. *Comprehensive Reviews in Food Science and Food Safety*, 20(4), 3579-3619. <https://doi.org/10.1111/1541-4337.12788>