Development of Date Fruit (*Phoenix dactylifera* L.) Wine

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Abstract

Date fruit (*Phoenix dactylifera* L.), known for its sweetness and nutrition, has been used to develop a low-alcohol wine suitable for health-conscious individuals who enjoy socializing. Current study aimed to select an appropriate yeast strain and to determine optimal conditions such as initial total soluble solids and pH for producing a healthy and appealing date fruit wine. Among seven strains of *Saccharomyces cerevisiae* examined (71B, BM4x4, ICV-D47, EC-1118, K1-V1116, QA23, RC212), strain K1-V1116 was found to produce a wine with lower pH and alcohol content, higher acidity, total phenolic content, and ferric reducing ability power. Date fruit wine made with strain K1-V1116 also received the highest scores for flavor and overall liking. Further experiments were conducted using date fruit juice with three levels of different initial total soluble solids (5 %, 10 %, and 15 %). The results indicated that 15 % initial total soluble solids produced wine with superior characteristics in terms of total soluble solids, pH, acidity, alcohol content, reducing sugar content, total phenolic content, ABTS radical cation decolorization, ferric reducing ability power compared to lower concentrations. Date fruit wine produced with 15 % initial total soluble solids also received the highest scores for color and overall liking. Additionally, the date fruit juice with 15 % initial total soluble solids was used to produce wine at three levels of pH value (4.0, 4.5, 5.0) and wines produced at pH 4.5 were rated the highest for flavor and overall liking. In conclusion, using S. *cerevisiae* K1-V1116 to ferment date fruit juice with 15 % initial total solids at pH 4.5 can yield a well-liked, low-alcohol wine.

Keywords: Date Fruit; Wine; Antioxidant

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Introduction

The date fruit (*Phoenix dactylifera* L.) originates from Central Asia and thrives in hot and arid climates. The date fruit comprises sugars, predominantly glucose and fructose, as well as proteins, fats, vitamins, and minerals. Dietary fibers and beta-carotene additionally contribute to the nutritional value of date fruits [1]. However, the lower value of individual fruits, ranging from 100 to 300 Baht per kg, often leads to the transformation into processed foods. Wine can be a rational choice for processing to increase its economic value due to a high sugar content of date fruit, which is conducive to the growth and alcoholic fermentation of wine yeast. In addition, bioactive compounds from date fruit could be integrated into wine products, reflecting the growing trend of functional beverages.

Previous study investigating bioethanol production from date palm fruit wastes indicated that the most favorable fermentation conditions involved the hydrolyzed date fruit with initial levels of reducing sugar ranging from 94 to 124 g/L. This process, utilizing 30 % inoculum of *Pichia kudriavzevii*, demonstrated optimal results at a temperature of 30 °C and pH levels between 5 and 6, resulting in ethanol yields of 4 - 6 % after a 96-hour period [2]. Another research outlined the conditions for converting date syrup into ethanol. They utilized flocculent *Saccharomyces uvarum*, fermenting 55 g/L sugar at a temperature of 29 °C [3]. Additionally, *Saccharomyces cerevisiae* was employed as 25 % inoculum to generate bioethanol from a solution derived from date palm waste. This solution contained 38 % glucose, fructose, and sucrose, and fermentation was carried out at pH 4 and 30 °C for 72 hours, resulting in a 15 % ethanol yield [4]. In another experiment, submerged ethanol fermentation was conducted using 4 % inoculum of *S. cerevisiae* with date waste syrup containing 180 g/L sugar. The syrup consisted of 13 % glucose, 10 % fructose, 32 % sucrose, and 1 g/L ammonium phosphate. After a 72-hour production period at 30 °C, this process yielded 136 g/L ethanol [5].

Low-alcohol wine is more appealing for health-conscious individuals who maintain an active social lifestyle. The composition of dates includes a notable concentration of phenolic compounds, known for their antimicrobial, antioxidant, anticancer, and antidiabetic properties [6] - [10]. However, there have been few studies on wine making from date fruit. Hence, the objective of this research was to select the suitable yeast strain, along with determining the optimal level of initial total soluble solids and pH value in date fruit juice to attain desirable wine characteristics. All the parameters studied had a significant impact on the organoleptic quality of wine. For instance, different commercial yeast strains produce varying levels of glycerol, acetaldehyde, sulfur dioxide, and volatile acids [11]. Additionally, the initial total soluble solids influence the alcohol content while the acidic pH enhances yeast growth and metabolism. Furthermore, the alcohol produced during fermentation may potentially facilitate the extraction of bioactive substances from date fruits, thereby enhancing the nutritional value of the wine product.

Materials and Methods

Raw Materials, Chemical Reagents, and Microorganisms

Dried date fruit cultivar Saidi was received from Thanarak Interfoods (Thailand). Citric acid, diammonium phosphate, potassium metabisulfite, sodium hydroxide, 3,5-dinitrosalicyclic acid (DNS), potassium sodium tartrate, glucose, Folin-Ciocalteu solution, sodium bicarbonate, gallic acid,

2,2'-azinobis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS), potassium persulfate, 95 % ethanol, 6-hydroxy-2,5,7,8-tetramethychroman-2-carboxylic acid (trolox), sodium acetate, acetic acid, hydrochloric acid, 2,4,6-tripyridyl-s-triazine (TPTZ), ferric chloride, ferrous sulfate, were received from Kemaus (Australia). Seven strains of *Saccharomyces cerevisiae*, including 71B, BM4x4, ICV-D47, EC-1118, K1-V1116, QA23, and RC212, were obtained from Lallemand Inc. (Canada).

Selection of Suitable Yeast Strain

Date fruit must was prepared by blending 750 g of dried date fruit in 1 L of RO drinking water to constitute 15 % total soluble solids (TSS). The must was boiled for 5 min before filtered through muslin cloth. Then, pH value was adjusted to 4.5 using citric acid. Citric acid content was determined by titration. Next, 0.2 g of diammonium phosphate and potassium metabisulfite were added. After 24 h of incubation at 25 °C, 0.2 g of lyophilized yeast was incorporated to date fruit must and fermentation was controlled at 25 °C. Samples were removed twice a week for analysis of total soluble solids, pH value, and citric acid content. When total soluble solids were stable, date fruit wine was separated from sediments by centrifugation at 3000 xg for 5 min and 0.2 g of potassium metabisulfite was added. After that, clarified wine was aged at 4 °C for a week. Then, alcohol content, reducing sugar content, total phenolic content, ABTS radical cation scavenging activity, and ferric reducing ability power were determined. Suitable yeast strain would produce date fruit wine with moderate levels of acid, alcohol, and reducing sugar, while also exhibiting high antioxidant activities and sensory scores.

Determination of Appropriate Initial Total Soluble Solids

Briefly, date fruit must was prepared by blending 250, 500, or 750 g of dried date fruit in 1 L of RO water to constitute 5 %, 10 %, or 15 % total soluble solids and the suitable yeast strain was incorporated to date fruit must. Appropriate initial total soluble solids would result in date fruit wine with moderate levels of acid, alcohol, and reducing sugar, while also showing high antioxidant activities and sensory scores.

Selection of Optimal pH Value

Briefly, date fruit must was prepared by blending appropriate amount of dried date fruit in 1 L of RO water. Then, pH value was adjusted to 4.0, 4.5, or 5.0 using citric acid and the suitable yeast strain was incorporated to date fruit must. Optimal pH value would produce date fruit wine with moderate levels of acid, alcohol, and reducing sugar, while also exhibiting high antioxidant activities and sensory scores.

Analysis of Physical Quality

Total Soluble Solids

Total soluble solids of date fruit wine were determined by hand refractometer (N-1E, Atago, Japan) and reported as percentage.

pH value

pH value of date fruit wine was determined by pH meter (FEP20, Mettler-Toledo, Switzerland).

Citric Acid Content

5 mL of date fruit wine was diluted in 95 mL of distilled water before titrated with 0.1 M NaOH until an end point at pH 8.2. After that, citric acid content was calculated by multiplying 0.12 with a volume of 0.1 M NaOH used and reported as percentage [12].

Alcohol Content

Alcohol content of date fruit wine was determined by Ebulliometer (Dujardin-Salleron, France) and reported as percentage.

Analysis of Chemical Quality

Reducing Sugar Content

0.5 mL of diluted sample was mixed with 0.5 mL of 0.1 % DNS and boiled for 10 min before dipped into ice water. Then, 5 mL of distilled water was added before OD measurement at 520 nm using distilled water as a blank [13]. Reducing sugar content was determined from a standard curve of glucose and reported as g/L.

Total Phenolic Content

0.25 mL of date fruit wine was mixed with 4.75 mL of 5 % Folin-Ciocalteu solution and left for 5 min. Then, 0.25 mL of 10 % sodium bicarbonate was added and left for 10 min. After that, OD was measured at 730 nm using distilled water as a blank [14]. Total phenolic content was determined from a standard curve of gallic acid and reported as gallic acid equivalent (GE; mM).

ABTS Radical Cation Scavenging Activity

ABTS radical cation scavenging activity was used to evaluate the hydrogen donating potential of date fruit wine. Briefly, ABTS radical cation was prepared by mixing 7 mM ABTS with 4.9 mM potassium persulfate at a ratio of 1:1 before stored in the dark for 16 h. Next, ABTS radical cation was diluted with 95 % ethanol at a ratio of 1:55 and OD was measured at 734 nm (OD1) using 95 % ethanol as a blank. Then, 0.02 mL of diluted sample was mixed with 2 mL of diluted ABTS radical cation and left at room temperature for 1 min before OD measurement at 734 nm (OD2). After that, % inhibition was calculated by (OD1 - OD2) / OD1 × 100 [15]. ABTS radical cation scavenging activity was determined from a standard curve of trolox and reported as trolox equivalent (TE; mM).

Ferric Reducing Antioxidant Power

Ferric reducing antioxidant power was used to evaluate the electron donating potential of date fruit wine. Briefly, FRAP solution was prepared by mixing 300 mM acetate buffer pH 3.6 with 10 mM TPTZ and 20 mM ferric chloride at a ratio of 10:1:1. Then, 0.1 mL of diluted sample was mixed with 3 mL of FRAP solution and 0.3 mL of distilled water before left at room temperature for 4 min. After that, OD was measured at 593 nm using FRAP solution as a blank [16]. Ferric reducing antioxidant power was determined from a standard curve of ferrous sulfate and reported as ferrous sulfate equivalent (FE; mM).

Analysis of Sensory Quality

Sensory properties, which were color, odor, flavor, and overall liking, of date fruit wine were evaluated by 50 untrained panelists, aged 20 - 50 years, using nine-point hedonic scale.

Statistical Analysis

All experiments were conducted using a randomized complete block design (RCBD) with three replications, and the results were presented as means ± standard error (SE). Alcohol content, reducing sugar content, total phenolic content, ABTS radical cation scavenging activity and ferric reducing antioxidant power were tested for statistical difference at 95 % confidence by Analysis of Variance in General Linear Model (GLM) followed by Duncan multiple range test (SPSS Statistics 17.0).

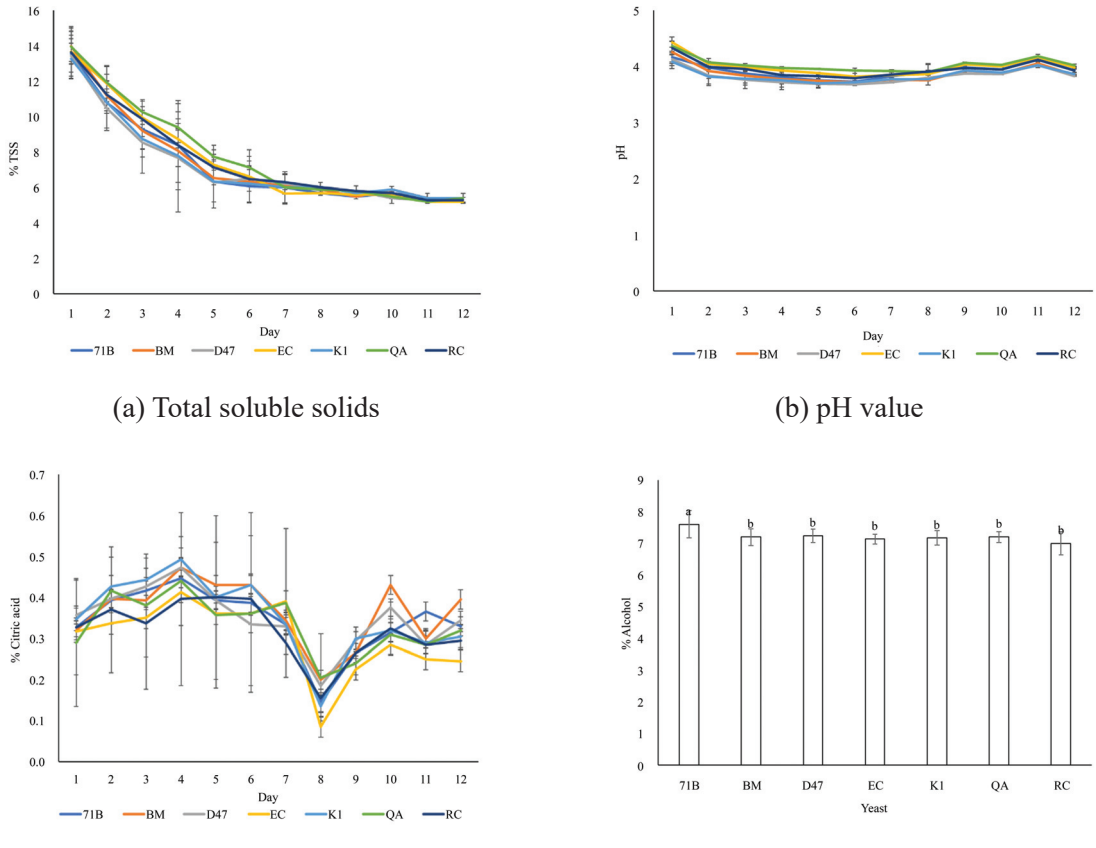
Results

Suitable Yeast Strain for Production of Date Fruit Wine

During the fermentation of date fruit juice, seven yeast strains were observed to reduce the total soluble solids (Figure 1(a)). Specifically, strains 71B and BM4x4 took nine days to stabilize the total

soluble solids, while strains ICV-D47 and QA23 required 10 days. The fermentation process for strains EC-1118, K1-V1116, and RC212 was completed after 11 days.

Similarly, pH values decreased during the first seven days of fermentation (Figure 1(b)), corresponding to the rise in acid content (Figure 1(c)). Afterward, pH values remained stable while acid contents declined and then rebounded after eight days. Ultimately, date fruit wine fermented by seven strains exhibited pH values between 3.8 and 4.0 and acid contents between 0.2 % and 0.4 %. Furthermore, strain 71B produced a statistically higher alcohol content compared to the other six strains, resulting in date fruit wine with approximately 7 % alcohol content (Figure 1(d)).



(a) Total soluble solids

(b) pH value

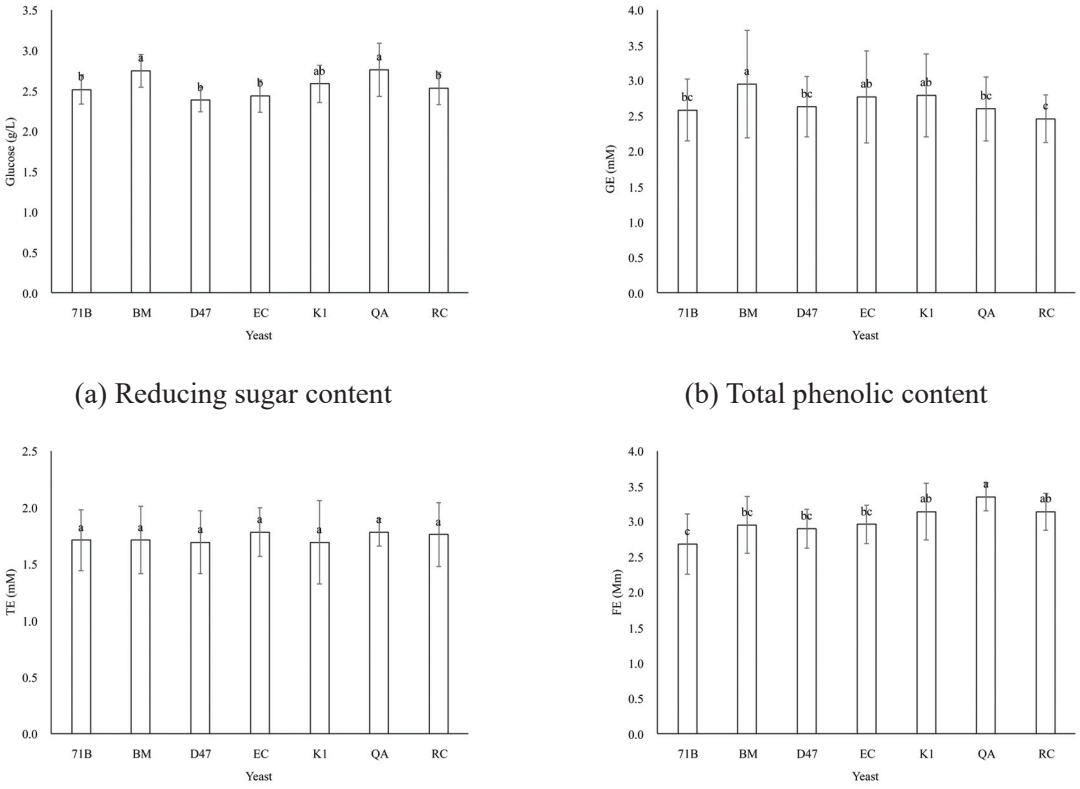
(c) Citric acid content

(d) Alcohol content

Figure 1 Physical properties of date fruit wine produced by different yeast strains.

Strains BM4x4 and QA23 exhibited higher reducing sugar content compared to the other five strains, resulting in the development of date fruit wine with approximately 2.5 g/L reducing sugar content (Figure 2(a)). Additionally, strain BM4x4 produced date fruit wine with the highest total phenolic content, whereas the other six strains displayed a total phenolic content of 2.7 mM GE (Figure 2(b)).

However, no statistical difference was found in the date fruit wine in terms of ABTS radical cation scavenging activity, which was approximately 1.7 mM TE (Figure 2(c)). In contrast, strains QA23 and 71B exhibited the highest and lowest ferric reducing antioxidant power, respectively (Figure 2(d)). The other five strains produced date fruit wine with a ferric reducing antioxidant power of 3.0 mM FE.



(a) Reducing sugar content

(b) Total phenolic content

(c) ABTS radical cation scavenging activity

(d) Ferric reducing antioxidant power

Figure 2 Chemical properties of date fruit wine produced by different yeast strains.

All seven yeast strains produced date fruit wine with non-significant variation in color, odor, and overall liking scores, all averaging approximately 3.3 out of 5.0 (Table 1). However, strain EC-1118 resulted in the lowest flavor liking score.

Table 1 Sensory properties of date fruit wine produced by different yeast strains.

Yeast strain	Color*	Odor*	Flavor**	Overall*
71B	3.22±0.98	3.30±1.11	3.25±0.93^{a}	3.22±0.87
BM	3.38±1.01	3.50±1.10	3.33±0.90^{a}	3.37±0.84
D47	3.23±0.93	3.28±0.99	3.30±1.03^{a}	3.27±1.02
EC	3.22±0.99	3.28±0.94	2.88±0.98^{b}	3.27±0.90
K1	3.22±1.15	3.37±1.07	3.42±0.98^{a}	3.53±1.08
QA	3.17±1.01	3.35±1.04	3.23±0.83^{a}	3.37±0.90
RC	3.20±1.10	3.15±1.02	3.15±0.99^{ab}	3.38±0.98

* There was no statistical difference.

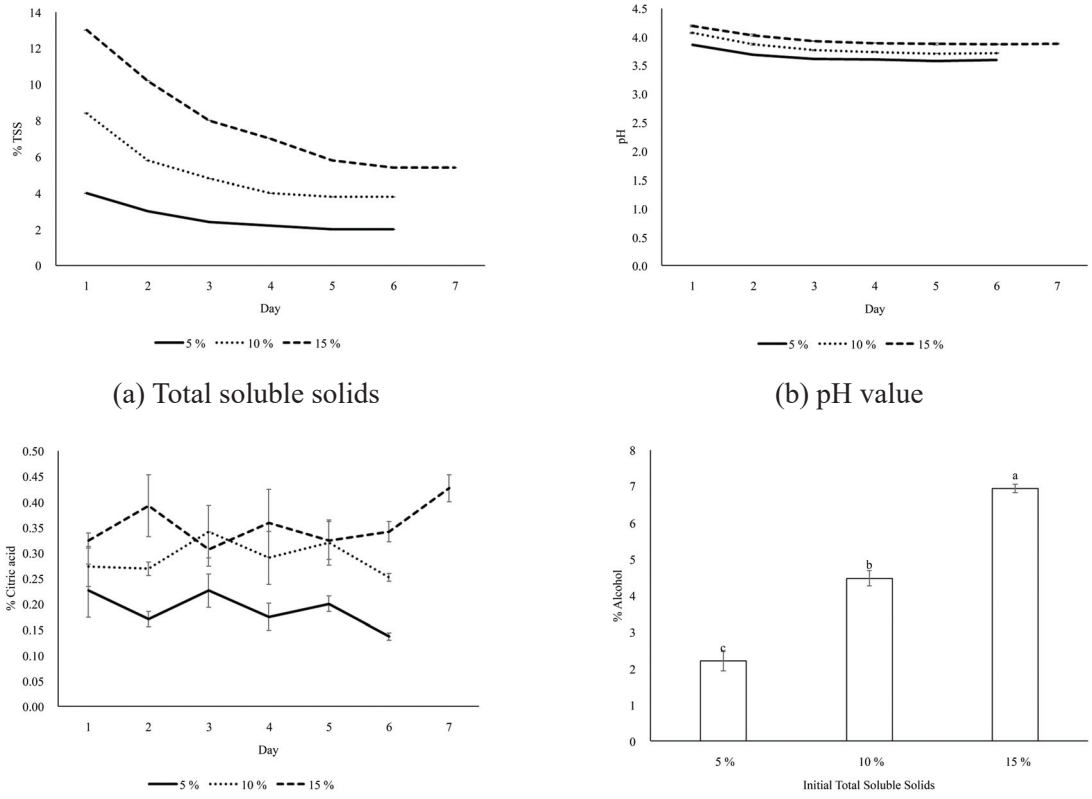
** Different letters indicated statistical differences within the same column.

Strain K1-V1116 produced date fruit wine with a low pH value of 3.8 and a relatively modest alcohol content of 7 %. Additionally, it exhibited relatively high levels of acid, reducing sugar, total phenolic, and ferric reducing ability power, at 0.3 %, 2.6 g/L, 2.8 mM GE, and 3.1 mM FE, respectively. Therefore, this strain was selected for further studies in the fermentation of date fruit wine.

Appropriate Initial Total Soluble Solids for Production of Date Fruit Wine

Similar to the first study, the total soluble solids of the date fruit wine continuously decreased. Date fruit must with initial total soluble solids of 15 % required longer fermentation time (Figure 3(a)). The final products prepared from 5 %, 10 %, and 15 % initial total soluble solids demonstrated total soluble solids of 2.0 %, 3.8 %, and 5.4 %, respectively. During the fermentation of date fruit must, there was a gradual decrease in pH values, corresponding to the initial total soluble solids (Figure 3(b)). Meanwhile, the acid contents remained relatively stable throughout the study period (Figure 3(c)). For date fruit wine made from initial total soluble solids of 5 %, 10 %, and 15 %, the pH values measured were 3.6, 3.8, and 3.9, respectively. In parallel, the acid contents were recorded as 0.2 %, 0.3 %, and 0.4 %, respectively.

Conversely, alcohol contents showed a significant increase corresponding to the initial total soluble solids (Figure 3(d)). Date fruit wine produced from initial total soluble solids of 5 %, 10 %, and 15 % exhibited alcohol contents of 2.2 %, 4.5 %, and 7.0 %, respectively.



(a) Total soluble solids (b) pH value

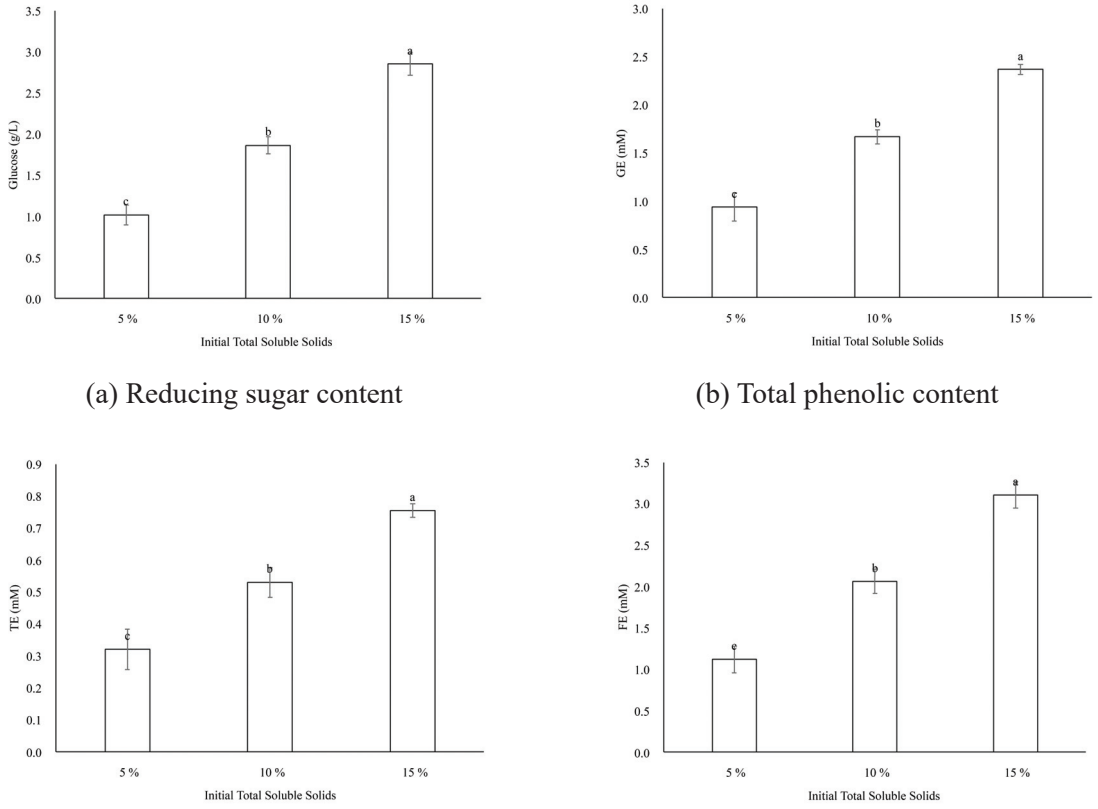
(c) Citric acid content (d) Alcohol content

Figure 3 Physical properties of date fruit wine produced from different initial total soluble solids.

The levels of reducing sugar, total phenolic, ABTS radical cation scavenging activity, and ferric reducing ability power in date fruit wine exhibited a significant increase corresponding to the initial total soluble solids. Final products derived from initial total soluble solids of 5 %, 10 %, and 15 % contained reducing sugar levels of 1.0, 1.9, and 2.9 g/L, respectively (Figure 4(a)), along with total phenolic contents of 0.9, 1.7, and 2.4 mM GE, respectively (Figure 4(b)).

In terms of antioxidant properties, date fruit wine crafted from initial total soluble solids of 5 %, 10 %, and 15 % demonstrated ABTS radical cation scavenging activities of 0.3, 0.5, and 0.8 mM TE,

respectively (Figure 4(c)). Additionally, the ferric reducing ability power was measured at 1.1, 2.1, and 3.1 mM FE, respectively, for the corresponding wine samples (Figure 4(d)).



(a) Reducing sugar content (b) Total phenolic content

(c) ABTS radical cation scavenging activity (d) Ferric reducing antioxidant power

Figure 4 Chemical properties of date fruit wine produced from different initial total soluble solids.

Date fruit wine produced from initial total soluble solids of 5 %, 10 %, and 15 % exhibited a notable variance in color liking scores, aligning with the corresponding initial total soluble solids (Table 2). However, there was no statistical difference observed in terms of odor, flavor, and overall liking scores, which ranged between 2.7 and 3.2 out of 5.0 (Table 2).

Table 2 Sensory properties of date fruit wine produced from different initial total soluble solids.

Initial TSS	Color*	Odor*	Flavor*	Overall*
5 %	2.55±1.14	2.73±1.13	2.95±0.93	3.17±0.99
10 %	3.27±0.76	2.83±0.99	3.00±0.88	2.95±0.95
15 %	3.75±0.95	2.98±1.21	3.08±1.28	3.12±1.37

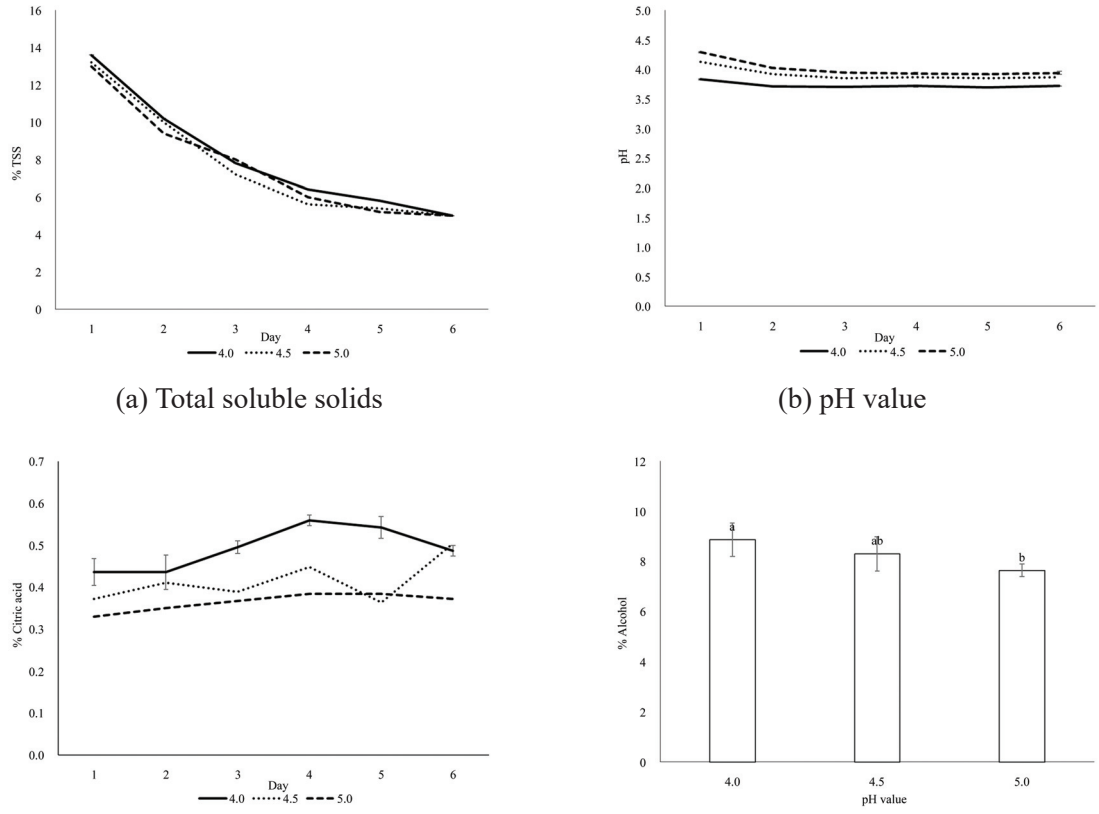
* There was no statistical difference.

Given that the date fruit must prepared from 15 % initial total soluble solids depicted the highest levels across various parameters including total soluble solids, pH value, acid content, reducing sugar, total phenolic compounds, ABTS radical cation scavenging activity, ferric reducing ability power, and color liking score, the subsequent study will focus on this concentration of 15 % initial total soluble solids.

Optimal pH value for Production of Date Fruit Wine

Consistent with previous studies, the total soluble solids and pH values of date fruit wine fermented at different pH levels showed a continuous decrease over time. In the final products, there was no significant variation with 5.0 % total soluble solids observed at all three conditions (Figure 5(a)). However, it's noteworthy that date fruit wine produced at pH 4.0 demonstrated a statistically lower pH value compared to the other two conditions (Figure 5(b)).

The acid contents in date fruit wine developed at different pH values remained relatively stable throughout the fermentation process, although the product at pH 5.0 displayed a statistically lower acid content (Figure 5(c)). Upon examination of alcohol contents in date fruit wine fermented at different pH values, there was a statistical decrease observed in alcohol contents corresponding to pH values, with pH 5.0 demonstrating the lowest alcohol content (Figure 5(d)).

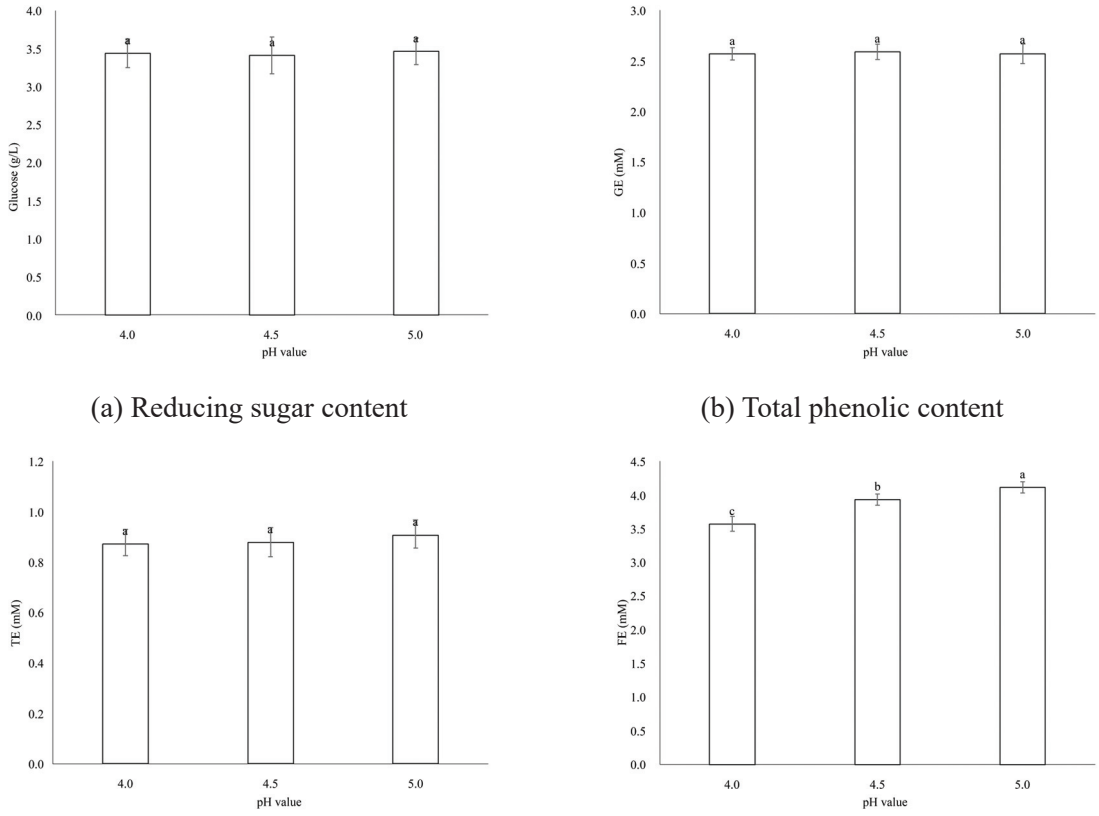


(a) Total soluble solids (b) pH value

(c) Citric acid content (d) Alcohol content

Figure 5 Physical properties of date fruit wine produced at different pH values.

When date fruit wine was fermented at different pH values, the levels of reducing sugar, total phenolic, and ABTS radical cation scavenging activity did not exhibit statistical significance, measuring at 3.4 g/L, 2.6 mM GE, and 0.9 mM TE, respectively (Figure 6(a) - (c)). However, it's worth noting that date fruit wine prepared at pH 5.0 displayed the statistically highest ferric reducing ability power, measuring at 4.1 mM FE (Figure 6(d)).



(a) Reducing sugar content (b) Total phenolic content

(c) ABTS radical cation scavenging activity (d) Ferric reducing antioxidant power

Figure 6 Chemical properties of date fruit wine produced at different pH values.

The sensory evaluation of date fruit wine fermented at different pH values revealed non-statistically different scores across various parameters. Scores for color, odor, flavor, and overall liking ranged between 3.1 and 3.5 out of 5.0 (Table 3).

Table 3 Sensory properties of date fruit wine produced at different pH values.

pH value	Color*	Odor*	Flavor*	Overall*
4.0	3.35±0.84	3.33±1.04	3.37±1.10	3.18±1.19
4.5	3.27±0.97	3.28±1.08	3.35±1.02	3.23±1.17
5.0	3.47±0.87	3.32±1.27	3.13±1.07	3.15±1.12

* There was no statistical difference.

Discussion

The decrease in total soluble solids observed during the fermentation process of date fruit wine could be attributed to the metabolic activities of yeast. Yeast metabolized sugars to produce energy, alcohols, and various other compounds such as organic acids and volatile compounds, while also generating heat and carbon dioxide [17] - [18]. As fermentation progressed, the pH value typically decreased due to the accumulation of organic acids. Date fruit wine originating from higher initial total soluble solids tended to exhibit elevated levels of acidity and alcohol compared to those from lower initial

concentrations. The initial sharp decline in pH values at the onset of fermentation was thought to be a result of carbon dioxide release, which formed carbonic acid upon dissolution [19]. Additionally, organic acids like citric acid, glutamic acid, succinic acid, fumaric acid, malic acid, and oxaloacetic acid, generated during yeast aerobic respiration, contributed to this pH reduction [20]. The yeast strain ICV-D47, known for its high beta-glucosidase activity, facilitated the hydrolysis of polysaccharides into sugars. These sugars were then converted into organic acids, ultimately resulting in date fruit wine with a lower pH value [11].

Definition of low-alcohol wines varies by country. For example, the United States considers wines with less than 8.5 % alcohol by volume to be low-alcohol, while the United Kingdom defines low-alcohol wines as those with less than 1.2 % alcohol by volume. [21]. Therefore, the date fruit wines produced in this study are not classified as low-alcohol products in some regions of the world. Moreover, red wines contained 1.0 - 4.2 g/L reducing sugars and 0.28 - 0.56 % total acids, resulting in a pH range of 3.0 - 4.1 [22]. In contrast, white wine had 0.1 - 0.4 g/L reducing sugars and 0.40 - 0.73 % total acids, leading to a pH range of 3.0 - 3.5 [23]. Although reducing sugars contribute to the sweetness of wine, they also promote the growth of undesirable microorganisms. In contrast, organic acids inhibit the microbial growth but result in the sourness of wine. Therefore, moderate levels of reducing sugars and total acids were preferred in this study.

Heat treatment at 100 °C during the preparation of date fruit must potentially led to a lower content of phenolic compounds compared to fresh date fruit juice, which typically ranged from 442 to 653 mM GE [24]. This suggested that phenolic compounds in date fruit were sensitive to heat or might become bound to other substances during wine fermentation [25]. However, it's noteworthy that date fruit wine contained phenolic compounds at levels comparable to herbal mead, even after undergoing heat treatment at 100 °C for 90 minutes [26]. Furthermore, different yeast strains exhibited varying abilities to form polyphenol-binding polysaccharides. For instance, strain BM4x4 stabilized phenolic compounds during growth but released them significantly after cell death, whereas strain RC212 showed a lower release of phenolic compounds post-death [11].

Ferric reducing ability power assessed the electron transfer capability of antioxidants like vitamin C, flavonoids, carotenoids, and phenolic acids to a ferric complex, which was then converted into a ferrous complex, resulting in a blue color [27]. Date fruit wine typically exhibited a lower level of ferric reducing ability power compared to fresh date fruit juice, which typically ranged from 77 to 83 mM FE [24], indicating the sensitivity of bioactive compounds in date fruit to heat. Variations in yeast metabolism also contributed to differences in levels of ferric reducing ability power. For instance, ability of strain 71B to oxidize isoamyl alcohol and acetic acid into isoamyl acetate could lead to decreased levels of reducing agents and consequently, lower FRAP levels in date fruit wine. Yeast-mediated melatonin synthesis also enhanced ferric reducing ability power, as melatonin served as a potent reducing agent compared to other compounds like vitamin C, vitamin E, glutathione, NADH, and NADPH [28]. Consequently, the antioxidant activity measured by DPPH and ABTS radical scavenging assays correlated with the melatonin content [29]. Additionally, yeast cells contained various antioxidants such as proteins, vitamin E, and carotenoids [30].

The date fruit wine fermented by strain K1-V1116, which received the highest flavor and overall liking scores, likely benefited from the formation of floral esters such as isoamyl acetate, hexyl acetate, and phenylethyl acetate [11]. Wines produced from a substantial amount of date fruit pulp, resulting in

high initial total soluble solids, exhibited elevated levels of reducing sugar, total phenolics, ABTS radical cation scavenging activity, and ferric reducing ability power. Date fruit pulp contained various bioactive compounds including polyphenols (ferulic acid, p-coumaric acid, gallic acid, proanthocyanidin), flavonoids (quercetin, rutin, apigenin), carotenoids (isoflavone, beta-carotene, lycopene, lignan), sterols, and tannins [9], [31]. The significant presence of date fruit pulp likely contributed to the dark color of wine, which was associated with consumer perceptions of a highly concentrated product, consequently leading to an excellent color liking score.

Fermentation at a low pH value yielded date fruit wine with reduced pH levels and ferric reducing ability power. This might be attributed to a higher concentration of protons in the wine, which could potentially bind to electrons from a ferrous complex. Conversely, fermenting wine at a low pH value encouraged yeast growth, leading to elevated levels of acidity and alcohol [32]. Although this research did not assess the microbiological quality of the wine product, no microbial growth was observed during storage at room temperature for a year (data not shown).

Conclusion

The optimal conditions for producing low-alcohol date fruit wine were determined to be the utilization of *S. cerevisiae* strain K1-V1116 to ferment the date fruit must prepared with 15 % initial total soluble solids at pH 4.5. The final product demonstrated moderate levels of pH, acid, and alcohol content, while also receiving the highest scores for flavor and overall liking.

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