OPTIMIZATION OF THE FERMENTATION PROCESS FOR BANANA (*Musa spp.*) – ROSELLE (*HIBISCUS SABDARIFFA* L.) WINE AT LABORATORY SCALE

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GENERAL INFORMATION

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ABSTRACT

This study was carried out to explore suitable fermentation conditions for producing wine from a mixture of bananas *(Musa spp.)* and Roselle *(Hibiscus sabdariffa* L.) flowers at the laboratory scale. The response surface methodology (RSM) using a Box–Behnken design was applied to examine the influence of initial total soluble solids (TSS) concentration (18–22 °Brix), yeast inoculation ratio (1–3% v/v), and fermentation time (120–168 hours) on the residual reducing sugar content and alcohol concentration in the final product. The most appropriate set of conditions was identified as 20 °Brix initial TSS, a yeast inoculation ratio of 2.48% (v/v), and a fermentation time of 152.1 hours, yielding a wine containing 9.86% (v/v) ethanol and 13.09 g/L reducing sugar. The yeast inoculation ratio and fermentation time showed clear effects on sugar utilization and alcohol production. The product underwent sensory assessment and routine quality analysis, both indicating satisfactory results. These outcomes suggest that combining bananas with *Hibiscus sabdariffa* L. may be a promising approach for developing a new tropical fruit wine with potential commercial and nutritional value. Future work could extend to larger-scale experiments, long-term stability evaluation, and tracking changes in bioactive compounds during fermentation.

1. INTRODUCTION

Banana *(Musa spp.)* is a staple fruit widely cultivated in tropical regions, especially in Southeast Asia and Africa. Bananas are well-known for their high natural sugar content, appealing aroma, and rich supply of essential nutrients such as potassium, fiber, and various vitamins, making them a popular food. However, their rapid ripening and short shelf life after harvest have contributed significantly to food loss in developing countries (Ogodo et al., 2015). This postharvest perishability has prompted research into sustainable processing methods, including converting overripe bananas into fermented products like wine and vinegar.

Roselle *(Hibiscus sabdariffa* L.), often referred to as red artichoke in Vietnam, is a flowering plant commonly appreciated for its bright-colored calyx, which is frequently used for making herbal teas and beverages. The calyx is rich in anthocyanins, organic acids, and ascorbic acid, which contribute to its red color and antioxidant capacity (Ire et al., 2020; Okoro, 2007). In several tropical regions, such as Nigeria, red artichoke is often fermented into "zobo," a local drink that has more recently served as a source for fruit wine production (Omole & Oranusi, 2019).

The wine fermentation process involves yeast converting sugars into alcohol and carbon dioxide. Among the various yeast strains, *Saccharomyces cerevisiae* is the most commonly used due to its strong fermentation ability and high alcohol tolerance. In the context of producing wine from *Hibiscus sabdariffa* L., *S. cerevisiae* strains isolated from traditional fermented wines have demonstrated good adaptability as well as high sugar conversion efficiency (Nwahia & Opara, 2012; Okoro, 2007). With its natural sweetness, banana becomes an ideal fermentation substrate, and when combined with *Hibiscus sabdariffa* L., it enhances both the sensory quality and alcohol content of the final product (Ogodo et al., 2015).

Recent studies have increasingly applied the response surface methodology (RSM) to optimize the fermentation process of tropical fruit wines, such as those made from papaya, citrus, and watermelon, due to its effectiveness in modeling complex process variables while reducing the number of trials required (Ire et al., 2020; Swami et al., 2014). However, while the individual fermentation processes of banana and roselle have been widely studied, their use together in the same fermentation system has received little attention.

This study was conducted to optimize fermentation conditions for producing wine from a mixture of banana and *Hibiscus sabdariffa* L. on a laboratory scale. By evaluating key variables including fermentation solution concentration TSS (°Brix), yeast ratio, and fermentation time, this study aimed to develop an effective process for creating a new, high-quality functional wine using locally available tropical fruits from Dong Nai province, Vietnam.

2. METHODOLOGY

2.1. Material

2.1.1. Banana and Hibiscus sabdariffa L.

Bananas and *Hibiscus sabdariffa L.* were purchased at Trang Dai Market, Trang Dai Ward, Dong Nai Province. The bananas were at ripeness level 3 (fully ripe); at this stage, the sugar content in the banana is at its highest and the starch content is at its lowest, with a moisture content of 72.2 ±1.15% and reducing sugar content of 38.5±2.8 g/L. *Hibiscus sabdariffa L.* flowers: The flowers were dried at 60°C using a Memmert UF 110 dryer until reaching a moisture content of 10%, after which 250 g of dried flowers were soaked in 1000 ml of boiling water for 20 minutes to obtain an extract. Bananas: → The bananas had total soluble solids of 13–14 °Brix, measured using a handheld refractometer (Vogel, Germany). They were then peeled and pureed using a Philips HR2041 blender for 1 minute at a flowers-to-water (*Hibiscus sabdariffa* L. extract) ratio of 1:3 (w/v). The banana mixture was then subjected to ultrasonic treatment using the GT-2120QTS ultrasound equipment at a fixed frequency of 40 kHz, the power was 400 W, the ultrasound mode was Normal, the ultrasonic temperature was 50 °C, and the sonication time was 15 minutes. Finally, the mixture was filtered to remove residue using a vacuum filter device with a pore size of 0.1 mm at a pressure of 600 mmHg to obtain the combined banana and *Hibiscus sabdariffa* L. extract.

2.1.2. Yeast

The yeast *Saccharomyces cerevisiae* was purchased from Saigon Yeast Co., Ltd., using the type intended for fruit wine production.

2.2. Methods

2.2.1. Fermentation of Banana and Hibiscus sabdariffa L. Wine

The extracted mixture was tested for TSS (total soluble solids) before adding saccharose to achieve the desired total soluble solids content according to study parameters. Fermentation was conducted in 5 L glass flasks with the specified proportion of yeast added as required. Fermentation conditions were maintained at room temperature, from 30-32°C, and at a pH of 3.5-4. The pH was adjusted using food-grade citric acid (10% w/v solution) and monitored with a Hanna HI2211 benchtop pH meter (Idise & Odum, 2011). After the fermentation period, the wine was filtered through coarse fabric (0.002 mm), and its quality was assessed.

2.2.2. Optimization of the Fermentation Process

The key fermentation parameters include the total soluble solids content, yeast inoculum density, and fermentation duration. Numerous studies on fruit-based wines have shown that maintaining TSS within 18–22 °Brix provides favorable conditions for the activity of *Saccharomyces cerevisiae* without imposing excessive osmotic stress (Okoro, 2007; Ogodo et al., 2015; Wang et al., 2013). A yeast inoculation level of 1–3% has been reported as appropriate for initiating a stable fermentation while minimizing contamination risks and avoiding nutrient competition among yeast cells (Jolly et al., 2014; Idise & Odum, 2011). A fermentation period of 120–168 hours has also been identified as the phase in which the most intensive sugar conversion occurs in studies on Hibiscus wine and banana wine (Nwahia & Opara, 2012; Omole & Oranusi, 2019; Ogodo et al., 2015).

The Box-Behnken method is used to optimize the wine fermentation process. Factors affecting Alcohol concentration and reducing sugar content include the concentration of the fermentation solution (TSS), yeast ratio, and fermentation time. The indicators monitored are alcohol concentration and reducing sugar content.

Table 1. Independent variables and their coded and actual values used for optimization

Facto	**Survey range**		
	–1	0	+1
X1- Initial TSS (°Brix)	18	20	22

Facto	Survey range		
	–1	0	+1
X2 - Yeast inoculation ratio (%)	1	2	3
X3-Fermentation time (hours)	120	144	168

2.2.3. Method for Determining Reducing Sugar

The quantification of reducing sugar content in fruit juice is carried out according to the method of (Miller, 1959). Specifically, 1 mL of 3,5-Dinitrosalicylic acid (DNS) solution is added to 1 mL of the supernatant (wort sample) in a test tube, then the mixture is heated in a water bath for 10 minutes. After heating, the test tube is rapidly cooled with tap water and distilled water is added to bring the total volume to 12 mL. At the same time, a blank sample is also prepared with 1 mL of distilled water and 1 mL of DNS. The optical density (OD) value of the sample is measured using an Implen C50 spectrophotometer at a wavelength of 540 nm against the blank sample. The concentration of reducing sugars is determined using the glucose standard curve $Y = 0.0005X – 0.0144$, $R^2 = 0.9875$.

Table 2. Experimental data on reducing sugar content and alcohol concentration in wine under different experimental factors of X1–Solution concentration, X2–Yeast ratio, X3–Fermentation time.

Run	X1- Initial TSS (ºBrix)	X2 - Yeast inoculation ratio (%)	X3-Fermentation time (hours)	Y1 - Reducing (g/L)	Y2 - Alcohol content (%)
1	18	1	144	30.60±0.44	4.56±0.28
2	18	2	120	20.60±0.6	5.24±0.3
3	18	2	168	16.90±0.21	7.14±0.26
4	18	3	144	15.70±0.4	7.92±0.28
5	20	1	120	38.40±0.59	6.18±0.41
6	20	1	168	31.70±0.8	6.92±0.73
7	20	2	144	15.10±0.4	9.12±0.37

Run	X1- Initial TSS (ºBrix)	X2 - Yeast inoculation ratio (%)	X3- Fermentation time (hours)	Y1 - Reducing (g/L)	Y2 - Alcohol content (%)
8	20	2	144	14.72±0.4	9.01±0.37
9	20	2	144	15.80±0.4	9.85±0.37
10	20	3	120	22.21±0.65	8.30±0.49
11	20	3	168	16.16±0.46	9.70±0.36
12	22	1	144	34.71±0.39	6.30±0.53
13	22	2	120	31.15±0.79	6.42±0.37
14	22	2	168	24.17± 0.78	7.61±0.57
15	22	3	144	24.80±0.81	7.30±0.5

2.2.4. Determination of Total Soluble Solids Content TSS (ºBrix)

To determine the sugar content in the sample, expressed as the total soluble solids (TSS) index or Brix degree, a handheld refractometer, Atago Master 20M (Japan), with a measuring range from 0 to 32°Brix, is used. Before measurement, samples are stabilized at room temperature. The device is initially calibrated using distilled water to ensure a reading of 0°Brix.

2.2.5. Determination of Alcohol Content in Wine

Alcoholic volatile compounds in the sample are separated using the distillation method, after which the density of the distillate is measured with a hydrometer. The alcohol content is calculated and converted according to the AOAC 2019 (945.07) method.

2.2.6. Sensory Evaluation Method

Sensory evaluation is conducted by a group of 10 fourth-year students from the Food Technology Department, Dong Nai University of Technology, including both male and female students aged 21-22. Each participant is served 10 mL of banana–Hibiscus sabdariffa L wine in a clear glass (25 mL capacity). The tasting sessions are held from 9:00 to 10:00 a.m. at room temperature (30–32 °C) and under white lighting in the sensory evaluation laboratory. The sensory evaluation procedure for the wine was carried out in accordance with the TCVN 3217-79 standard.

3. FINDINGS AND DISCUSSION

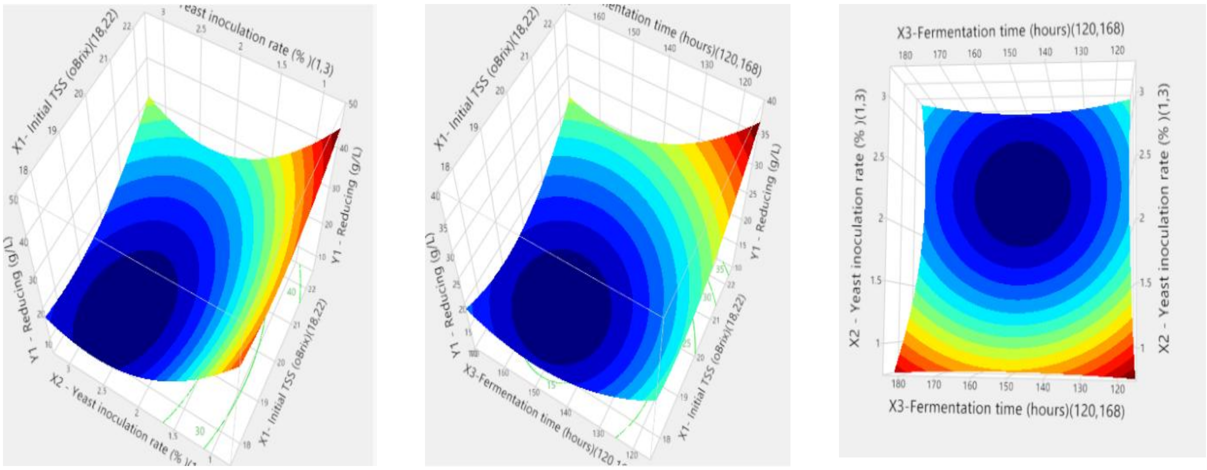
3.1. Influence of Factors on the Reducing Sugar Content

In wine production, the conversion of sugars into alcohol and aroma-active compounds is a central step in the fermentation process. The remaining reducing sugars in the fermentation broth are used as an indicator**,** showing how well the yeast functions and how far the reactions have progressed**.** Excess residual sugar may lead to undesirable post-fermentation or off-flavors. For this reason, tracking and measuring reducing sugars is important for maintaining a stable and uniform final product (Fleet, 2008).

Optimizing the reducing sugar content during wine fermentation is aimed at assessing how effectively yeast converts sugar into alcohol . The optimization process was carried out using JMP 16 software with the Box-Behnken method. The mathematical model demonstrated a high level of compatibility among the experimental factors, reaching an R^2 value of 0.98, RMSE = 1.3984, and Lack-of-Fit (p=0.0907) p >0.05. The factors affecting reducing sugar content in wine are presented in the following regression equation (1) và table 3.

$$Y_1 = 15 + 3.8\ X_1 - 7.06X_2 - 2.92\ X_3 + 3.6\ X_1^2 + 7.57\ X_2^2 + 4.33\ X_3^2 \quad (1)$$

In which Y_1 is the reducing sugar content (g/L); X_1 is the initial TSS (°Brix); X_2 is the yeast ratio (% v/v); X_3 is the fermentation time (hours)



(a) (b) (c)

Figure 1. Response surface of Reducing (g/L): (a) X1- Initial TSS (ºBrix) và X2-Yeast inoculation ratio (%); (b) X2 - Yeast inoculation ratio (%) và X3 - Fermentation time (hours); (c) X1- Initial TSS (ºBrix) và X3 - Fermentation time (hours).

Table 3. Effect of factors on the remaining reducing sugar content of the final fermented product

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	15.206667	0.807391	18.83	<.0001*
X1- Initial TSS (°Brix)(18,22)	3.87875	0.494424	7.84	0.0005*
X2 - Yeast inoculation rate (%)(1,3)	-7.0675	0.494424	-14.29	<.0001*

Term	Estimate	Std Error	t Ratio	Prob>|t|
X3-Fermentation time (hours)(120,168)	-2.92875	0.494424	-5.92	0.0020*
X1- Initial TSS (°Brix)*X2 - Yeast inoculation rate (%)	1.2475	0.699221	1.78	0.1345
X1- Initial TSS (°Brix)*X3-Fermentation time (hours)	-0.82	0.699221	-1.17	0.2937
X2 - Yeast inoculation rate (%)*X3-Fermentation time (hours)	0.1625	0.699221	0.23	0.8254
X1- Initial TSS (°Brix)*X1- Initial TSS (°Brix)	3.6666667	0.727772	5.04	0.0040*
X2 - Yeast inoculation rate (%)*X2 - Yeast inoculation rate (%)	7.5791667	0.727772	10.41	0.0001*
X3-Fermentation time (hours)*X3-Fermentation time (hours)	4.3316667	0.727772	5.95	0.0019*

Based on regression equation (1) and the plots in Figure 1. The results indicate that the initial sugar concentration influences the residual sugar content after fermentation. When the fruit juice contains higher initial sugars, a greater portion often persists in the final product. In contrast, adding more yeast and allowing the fermentation to run longer generally promote stronger sugar utilization, which explains the lower residual levels observed in those treatments.

A higher inoculum provides yeast cells with a quicker start, allowing them to consume sugars for growth and alcohol formation at a faster pace. Likewise, extending the fermentation period gives the yeast additional time to break down sugars. As a result, the wine contains noticeably less residual sugar. These yeast-related factors, therefore shape not only the kinetics of sugar conversion but also the sensory profile and stability of banana–roselle wine.

This trend aligns with previous findings, such as the reduction in glucose during grape juice fermentation reported by Ezemba & Archibong (2022) and the sugar-consumption patterns observed in banana substrates fermented with *Saccharomyces cerevisiae* (Idise & Odum, 2011). Collectively, these results highlight that the way reducing sugars are metabolized plays an important role in determining the chemical composition and sensory attributes of the final wine (Fleet, 2008).(Fleet, 2008)

3.2. Influence of Factors on Alcohol Content in Wine

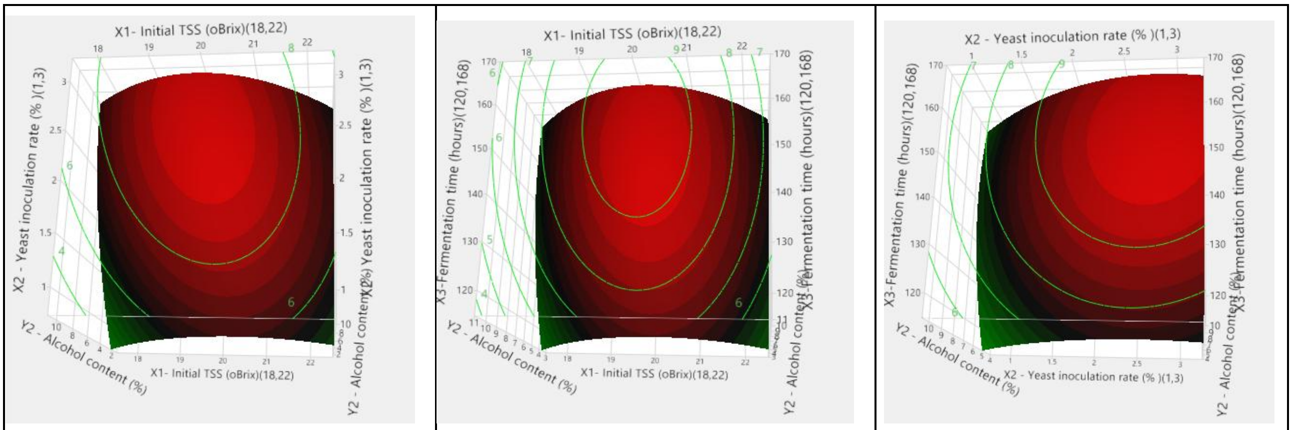
Alcohol content is a key parameter that determines the quality and sensory characteristics of wine. Various factors such as the total soluble solids content (TSS), yeast inoculation ratio, and fermentation time can affect the amount of alcohol produced. Studying these relationships helps optimize the production process (Fleet, 2008; Idise & Odum, 2011).

The variance analysis combined with the corresponding t-tests demonstrates that the three experimental variables-initial soluble solid content (X_1), the proportion of yeast added (X_2), and the duration of fermentation (X_3)-all contribute significantly to changes in alcohol concentration ($p < 0.05$). The non-significant Lack-of-Fit value ($p = 0.83$) confirms that the constructed model is appropriate and adequately represents the experimental data. Among the factors examined, the yeast inoculation level shows the strongest statistical effect, indicating that this parameter plays the most influential role in determining the amount of alcohol produced.

The relationship between the independent variables and the response (alcohol content) is described by the following second-order regression equation:

$$Y_2 = 9.32 + 0.34\,X_1 + 1.15X_2 + 0.65\,X_3 - 1.98\,X_1^2 - 0.81\,X_2^2 - 0.73\,X_3^2 \quad (2)$$

In which, Y_2 is the Alcohol content (%); X_1 is the initial TSS (°Brix); X_2 is the yeast ratio (% v/v); X_3 is the fermentation time (hours).



(a) (b) (c)

Figure 2. Response surface of Alcohol content (%):(a) X1- Initial TSS (°Brix) và X2-Yeast inoculation ratio (%); (b) X2 - Yeast inoculation ratio (%) và X3 - Fermentation time (hours); (c) X1- Initial TSS (°Brix) và X3 - Fermentation time (hours).

Table 4. Effect of factors on the alcohol content of the fermented product

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	9.3266667	0.200207	46.59	<.0001*
X1- Initial TSS (°Brix) (18,22)	0.34625	0.122601	2.82	0.0369*
X2 - Yeast inoculation ratio (%) (1,3)	1.1575	0.122601	9.44	0.0002*

Term	Estimate	Std Error	t Ratio	Prob>|t|
X3-Fermentation time (hours) (120,168)	0.65375	0.122601	5.33	0.0031*
X1- Initial TSS (^{o}Brix)*X2 - Yeast inoculation ratio (%)	-0.59	0.173384	-3.40	0.0192*
X1- Initial TSS (^{o}Brix)*X3-Fermentation time (hours)	-0.1775	0.173384	-1.02	0.3529
X2 - Yeast inoculation ratio (%)*X3-Fermentation time (hours)	0.165	0.173384	0.95	0.3850
X1- Initial TSS (^{o}Brix)*X1- Initial TSS (^{o}Brix)	-1.989583	0.180464	-11.02	0.0001*
X2 - Yeast inoculation ratio (%)*X2 - Yeast inoculation ratio (%)	-0.817083	0.180464	-4.53	0.0062*
X3-Fermentation time (hours)*X3-Fermentation time (hours)	-0.734583	0.180464	-4.07	0.0096*

Drawing on regression equation (2) together with Figure 2 and the data in Table 4, the patterns in alcohol formation suggest that the levels of TSS and the amount of yeast added influence one another during fermentation. When both variables are increased beyond suitable ranges, the yeast tends to convert sugars to alcohol less efficiently. A likely reason for this is the rise in osmotic pressure at high sugar concentrations, which slows yeast activity, while an overly dense yeast population may compete for nutrients and accumulate metabolites that interfere with fermentation.

The negative quadratic terms for X_1, X_2, and X_3 also indicate that each parameter operates best within a specific window rather than at extreme values. Moving outside these ranges can reduce alcohol production because the enzymes involved in fermentation become less effective when conditions are unfavorable. For this reason, achieving high alcohol content in banana–*Hibiscus sabdariffa* L. wine requires balancing the starting TSS, the yeast inoculation level, and the fermentation duration. Similar observations have been reported in previous studies examining how initial sugar concentration and inoculum size alter the ability of *Saccharomyces cerevisiae* to convert sugars into alcohol (Jolly et al., 2014; Malacrinò et al., 2005).

3.3. Optimization of the Wine Fermentation Process

From Figure 3 the optimization results using the Box-Behnken response surface methodology showed a desirability value of 0.96, reflecting the model’s high predictive capability and strong reliability in determining optimal operating conditions. The optimal parameters were identified as follows: Initial Brix (X_1) at 20 °Brix, Yeast inoculation ratio (X_2) at 2.48% v/v, and Fermentation time (X_3) at 152.1 hours (~6.3 days). Under these conditions, the predicted response values were: Residual reducing sugar content (Y_1): 13.09 g/L; alcohol concentration (Y_2): 9.86% v/v.

The results show that the fermentation process achieved an optimal balance between sugar conversion efficiency and the limitation of by-product accumulation. The total soluble solids (TSS) concentration at 20% provides a sufficient carbon source for the growth of *Saccharomyces cerevisiae* yeast without causing osmotic inhibition, while a yeast inoculation ratio of 2.48% v/v ensures the appropriate cell density for a rapid fermentation start, and at the same time limits nutrient competition. The incubation time of about 152 hours is long enough to convert most of the sugar into alcohol but not long enough to produce by-products that would negatively affect sensory quality. Compared with previous studies, the optimal alcohol content obtained (≈10% v/v) is higher than that reported for the fermentation of *Hibiscus sabdariffa* L. flowers with *S. cerevisiae* under initial sugar conditions of 18°Brix (Omole & Oranusi, 2019). Similarly, (Wang et al., 2013), when optimizing wine production from mulberries, also recorded an ethanol concentration ranging from 9–11% v/v with inoculum ratio in the 2–3% range. In addition, the study by (Jolly et al., 2014) also emphasized the decisive role of the initial inoculation ratio in the fermentation start-up speed and efficiency. Thus, the results of this study are consistent with the general trend, demonstrating the potential application of the optimized process in the production of wine from tropical raw materials such as banana and Hibiscus sabdariffa.

The findings of {Ogodo, 2015 #96} demonstrated that blending different fruits for wine production resulted in relatively high ethanol yields. The final alcohol concentrations were 17.50 ± 0.02% for papaya–watermelon wine, 16.00 ± 0.02% for papaya–banana, 18.50 ± 0.02% for banana–watermelon, and 18.00 ± 0.02% for the papaya–banana–watermelon mixture. These values were markedly higher than the 10% alcohol obtained in the present study on banana–Hibiscus sabdariffa L. wine. This difference could be attributed to the yeast strain used by {Ogodo, 2015 #96} which was isolated from palm wine and possesses a stronger fermentative capacity, thereby yielding higher alcohol levels.

3.4. Laboratory-Scale Fermentation Testing of Banana –Roselle Wine and Product Quality Evaluation.

The experimental production process of wine from bananas combined with *Hibiscus sabdariffa* L. flowers was carried out on a 5-liter scale, applying the optimal conditions determined in previous experiments. The resulting product was evaluated by a group of 10 members at the Sensory Practice Room – Faculty of Technology, based on sensory criteria using the scoring method specified in the Vietnamese Standard TCVN 3217:79

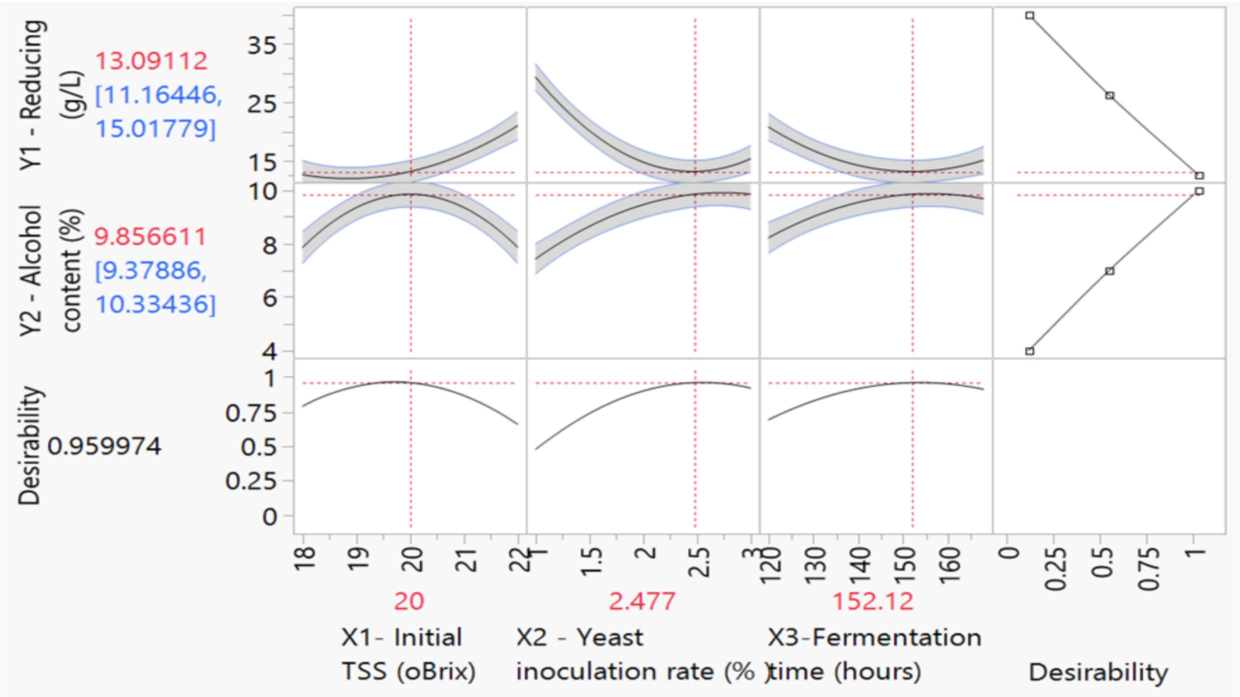


Figure 3. Prediction profile analysis of alcoholic fermentation

The results showed that the wine sample had a bright red color, clear transparency, no turbidity, and a gentle, pleasant aroma. Based on the data in Table 5 and according to the quality classification scale set by TCVN 3217-79, the Banana – *Hibiscus sabdariffa* L. wine sample achieved a total score of 16.5, corresponding to the "Good" rating. This demonstrates that the wine fermented by *Saccharomyces cerevisiae* possesses sensory characteristics that are well accepted by consumers and has received positive evaluations.

In addition, the physicochemical indicators of the wine were also checked according to the regulations in QCVN 6-3:2010/BYT issued by the Ministry of Health. The results presented in Table 6 show that the product fully meets the safety limits for alcoholic beverages. Specifically, analytical parameters such as methanol content, ethanol, arsenic, lead, and the total number of aerobic microorganisms were all below the maximum allowable limits according to current standards.

Table 5. Sensory evaluation results of Banana wine – *Hibiscus sabdariffa* L.

Target	**Scores of the members**										Total score	Grade point average	Important coefficient	Weighted score
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**				
Color, clarity	4	5	5	4	4	4	5	5	4	5	45	4.5	0.8	3.6

Target	**Scores of the members**										Total score	Grade point average	Importa nt coeffici ent	Weighted score
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**				
Smell	5	5	4	2	3	4	4	3	5	4	39	3.9	1.2	4.7
Taste	5	4	2	4	4	4	5	4	5	4	41	3.9	2.0	8.2
Total														16.5

Table 6. Results of physico-chemical and microbiological evaluations of Banana – *Hibiscus sabdariffa* L. wine.

Indicator name	**Test Method**	**Limit of detection**	**Test results**
Ethanol content at 20°C, % v/v	AOAC 2019 (945.07).	-	10.1
Methanol content, mg/L of 100° alcohol	AOAC 2016 (972.11)	3.0	Not detected
Lead content, mg/L	QTTN/KT3 098:2016	1.80×10^{-2}	Not detected
Total Arsenic content, mg/L	TCVN 8427:2010	1.00×10^{-2}	Not detected
Total aerobic microorganisms	ISO 4833-1:2013	-	4.7×10^{2}

Note: The wine sample was sent for analysis at the Quartest 3 Testing and Analytical Service Center – Bien Hoa, Dong Nai (test result sheet KT3-01913BTB4 dated 10/4/2024).

Figure 4. Banana (*Mussa spp*.) – Roselle *(Hibiscus sabdariffa* L._ wine product

4. CONCLUSION

The banana–*Hibiscus sabdariffa* L. wine was produced using *Saccharomyces cerevisiae* under controlled fermentation conditions. Based on the Box–Behnken analysis, the most suitable conditions were an initial TSS of 20 °Brix, a yeast inoculation level of 2.48%, and a fermentation time of about 152 hours. Under this set of parameters, the wine reached an ethanol level of 9.86% (v/v) and contained 13.09 g/L of residual reducing sugars. Both the yeast dosage and the fermentation duration showed clear effects on sugar utilization and ethanol formation, supporting an efficient conversion process and contributing to product stability.

Sensory assessment showed that the wine had a bright red appearance, a mild aroma, and a balanced taste, with scores corresponding to an "above average" rating on the 5-point scale. In addition, the physicochemical values fell within the allowable limits for alcoholic beverages according to national regulations. The findings suggest that combining banana and *Hibiscus sabdariffa* L. offers promise for developing a tropical fruit wine with commercial potential and favorable nutritional attributes. Future work may involve scaling up the process, monitoring long-term stability, and examining changes in bioactive compounds during storage and fermentation.

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TỐI ƯU HÓA QUÁ TRÌNH LÊN MEN RƯỢU VANG CHUỐI – ATISO ĐỎ QUY MÔ PHÒNG THÍ NGHIỆM

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THÔNG TIN CHUNG

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TỪ KHOÁ

Chuối;
Hibiscus sabdariffa L.*;*
Lên men;
Rượu vang.

TÓM TẮT

Nghiên cứu này nhằm tối ưu hóa các điều kiện lên men để sản xuất rượu vang từ hỗn hợp chuối và Atiso đỏ ở quy mô phòng thí nghiệm. Phương pháp bề mặt đáp ứng (RSM) với thiết kế Box-Behnken được sử dụng để đánh giá ảnh hưởng của nồng độ chất hòa tan tổng số (TSS) ban đầu (18-22 °Brix), tỷ lệ cấy nấm men (1-3% v/v) và thời gian lên men (120-168 giờ) đến hàm lượng đường khử còn lại và nồng độ ethanol trong sản phẩm cuối cùng. Các thông số tối ưu được xác định gồm 20 °Brix TSS ban đầu, tỷ lệ cấy nấm men 2,48% (v/v) và thời gian lên men 152,1 giờ, cho sản phẩm rượu có 9,86% (v/v) ethanol và 13,09 g/L đường khử. Tỷ lệ nấm men và thời gian lên men được chứng minh là có ảnh hưởng đáng kể đến quá trình tiêu thụ đường và hình thành ethanol. Sản phẩm được đánh giá cảm quan và phân tích các chỉ tiêu cho thấy sản phẩm đạt yêu cầu. Kết quả nghiên cứu khẳng định tiềm năng kết hợp chuối và Atiso đỏ để phát triển một loại rượu vang nhiệt đới mới, vừa có giá trị thương mại vừa mang đặc tính dinh dưỡng. Các nghiên cứu tiếp theo nên tập trung vào thử nghiệm ở quy mô lớn, đánh giá độ ổn định lâu dài và theo dõi sự biến đổi của các hợp chất sinh học hoạt tính trong suốt quá trình lên men.