Optimization of Fermentation Process for the Preparation of Coffee Wine by Response Surface Methodology

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Abstract

Coffee is one of the most widely consumed beverages and its consumption has become a regular part of daily life worldwide. Coffee contains different types of chemicals including carbohydrates, lipids nitrogenous compounds, vitamins, minerals, alkaloids and phenolic compound and its consumption is used for social activity, leisure, improvement of work performance and well-being. There are different kinds of coffee beverages characterized by different nuances in terms of body, aroma, acidity and astringency. Coffee wine is one of the alcoholic beverages made from coffee by using yeast, saccharomyces cerevisiae. In the present study, process conditions viz: yeast, citric acid and diammonium phosphate were optimized by response surface methodology for the preparation of coffee wine. Box-Behnken experimental design was formulated for the different levels of yeast, citric acid and diammonium phosphate. Yeast consumes sugar and converts it to ethanol, carbohydrates and heat. Diammonium phosphate was used as a yeast nutrient in wine making. Citric acid was added to adjust the pH level, around that the yeast favours for its fermentation. Second order response surface regression model was fitted to the experimental data with an R^2 value of 0.99. After one month of fermentation period, the alcohol content of prepared coffee wine was determined by Sike's hydrometerto obtain the optimum conditions. According to the results, the optimum condition for the preparation of coffee wine was found to be0.4 %(w/w) of yeast, 0.55%(w/w) of citric acid and 0.12% (w/w) of diammonium phosphate for fermenting 15g of coffee powder.

Keywords: Coffee wine, Yeast, Citric acid, Diammonium phosphate, Response surface methodology

.Introduction

Coffee has taken an important place in human society for at least 1200 years. Today, coffee is one of the most widely consumed as beverages and its consumption has become a regular part of daily life worldwide. Coffee is a complex mixture of chemicals and is the main source of caffeine in many populations. It contains thousands of different chemicals including carbohydrates, lipids, nitrogenous compounds, vitamins, minerals, alkaloids and phenolic compound. Coffee consumption is used for social activity, leisure, improvement of work performance, and well-being. Coffee is not only a medicinal alternative but also a beverage containing numerous potential benefits. (integrative medicine research, volume 3, Issue 4, December 2014)

Wine is an alcoholic beverage typically made through fermentation process since thousands of years and many varieties of wine are made throughout the world. Coffee wine is one such beverage produced from coffee powder through fermentation. There are different kinds of coffee beverages characterized by different nuances in terms of body, aroma, acidity and astringency.Nowadays, consumers can choose the most preferred type of beverage form the most full-bodied to the lightest flovours, organic or conventional, pale dark or with fruited flavor essences (www.livestrong.com/article/148262-side-effects-of-coffee-wine-in-human-health/). The present study optimized the fermentation process for conditions viz: yeast, citric acid and diammonium phosphate for coffee wine preparation by response surface methodology (RSM).

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Materials and Methods

Raw Materials

Arabica coffee beans, come from Ywa Ngan, were purchased from Ywa Ngan village, Shan state, to prepare coffee wine. Sugar, citric acid, yeast, yeast nutrients and distilled water were purchased from local markets and Able chemical store, Mandalay.

Experimental Design

Box-Behnken experimental design with 3 central points was formulated using Design Expert 7.1 . The experimental design contains 15 runs for varying levels of yeast, citric acid and diammonium phosphate. the experimental design with coded values is given in Table 1.

Table 1. Levels of factors used for optimization of coffee wine production

Coded Levels	Factors		
	$\varkappa_1$ Yeast(g)	$\varkappa_2$ Citric acid(g)	$\varkappa_3$ Diammonium phosphate(g)
-1	0.3	0.45	0.08
0	0.35	0.5	0.1
1	0.4	0.55	0.12

Experimental Procedure

Arabica coffee beans were weighed and crushed by using grinder to obtain finely divided coffee powder. Then, it was passed through the 200 mesh screen to obtain uniform size of coffee powder. Brown sugar (71 g) was dissolved in 250 ml of boiling water to obtain sugar syrup.The prepared sugar syrup was added to 15 g of coffee powder and mixed well. The mixture was allowed to stand for 30 minutes for brewing process. The pH of the coffee was 6 and it was needed to acidified through acid media. After brewing process, the mixture was filtered to separate filtrate and residue. Different levels of dry yeast, saccharomyces cerevisiae was activated in the warm water, then, diffenrt levels of citric acid, 0.3 g of yeast *saccharomyces cerevisiae* and 0.1 g of yeast nutrients and different levels of diammonium phosphate were added to the filtrate and stirred thoroughly. The mixture was poured into the pre-sterilized bottle and stored to ferment at room temperature for 5 days. After 5 days, CO_2 gas was evolved from fermentation bottle and allowed the fermentation bottle to release the evolved CO_2. When fermentation was slow down, the mixture was racked out of the pre-sterilized bottle and aged for one month. After the separation and fine filteration, coffee wine was obtained. Finally, coffee wine was stored in cool and dark place.

Ethanol determination

The alcohol content of coffee wine was determined by Sike's hydrometer. The amount of yeast, citric acid and diammonium phosphate were varied from 0.3 - 0.4 g, 0.45 - 0.55g and 0.08 -0.12g respectively.

Statistical Model Development

Second order response surface regression model was used to predict as a function of input variables.

$y=\beta_0 + \beta_i \varkappa_i + \beta_{ij} \varkappa_i \varkappa_j + \beta_{ii} \varkappa_i^2 + e, i = 1,2,3,$

where y =Alcoholocity (%)

$\varkappa_1$= Yeast, $\varkappa_2$= Citric acid and $\varkappa_3$= Diammonium phosphate,

β_0, β_i, β_{ij} and β_{ii} are intercept, linear, interaction and quadratic regression coefficients. Further e is the error term assumed to follow normal distribution with constant variance.

The regression coefficients were estimated by ordinary least square method. The goodness of fit of the model was assessed by R^2, adj R^2 and RMSE values.The optimum process condition was obtained by formulating a desirability function for maximizing the alcoholicity percentage. All the analysis was carried out using Design Expert 7.1.

Results and Discussion

Determination of alcoholicity using Sike's hydrometer

By using Sike's hydrometer, alcoholicity fermented from brewing of coffee were evaluated. The results of alcoholicity (%) for different experimental combinationsof Box-Behnken experimental design are given in Table 2.

Table 2. Response values of Alcoholicity

Runs	$\varkappa_1$	$\varkappa_2$	$\varkappa_3$	Alcoholicity(y%)
1	1	0	1	12.45
2	-1	0	1	10.65
3	-1	-1	0	9.93
4	0	1	-1	10.8
5	0	0	0	9.1
6	0	-1	1	10.4
7	-1	1	0	10.14
8	-1	0	-1	11.83
9	1	0	-1	9.97
10	1	1	0	10.85
11	1	-1	0	9.8
12	0	-1	-1	10.6
13	0	1	1	12
14	0	0	0	9.1
15	0	0	0	9.2

Optimization of fermentation conditions

Second order response surface regression model was fitted to the experimental data with an R^2 value of 0.99. The fitted model along with regression coefficients is given below

$$Y=9.13+0.0650\varkappa_1+0.3825\varkappa_2+0.2875\varkappa_3+0.2100\varkappa_1\varkappa_2+0.9150\varkappa_1\varkappa_3+0.3500\varkappa_2\varkappa_3+$$

$$0.6608\varkappa_1^2+0.3835\ \varkappa_2^2+1.43\ \varkappa_3^2\ ,\ R^2 = 0.99$$

The selected model was found to be significant ($p < 0.01$) as it explained 99% percentage of variability in Alcoholicity (%) as function of input variables. The linear, interaction and quadratic regression coefficients of yeast ($\varkappa_1$), citric acid ($\varkappa_2$) and diammonium phosphate ($\varkappa_3$) was found to significant ($p < 0.05$) except for linear regression coefficient of yeast. The results of analysis of variance (ANOVA) are given in Table 3. The lack of fit of the model was non-significant ($p>0.05$) indicates the adequacy of the fitted model for predicting the response variable.

Table3.ANOVA for the regression response surface model

Source	Sum of Square	df	Mean Square	F value	P-value Prob>F	significant
Model	14.78	9	1.64	77.76	< 0.0001	**
$\varkappa_1$	0.0338	1	0.0338	1.60	0.2615	
$\varkappa_2$	1.17	1	1.17	55.44	0.0007	**
$\varkappa_3$	0.6612	1	0.6612	31.32	0.0025	**
$\varkappa_1\ \varkappa_1$	0.1764	1	0.1764	8.35	0.0342	*
$\varkappa_1\ \varkappa_3$	3.35	1	3.35	158.62	< 0.0001	**
$\varkappa_2\ \varkappa_3$	0.4900	1	0.4900	23.21	0.0048	**
$\varkappa_{12}$	1.61	1	1.61	76.37	0.0003	**
$\varkappa_{22}$	0.5497	1	0.5497	26.03	0.0038	**
$\varkappa_{32}$	7.56	1	7.56	358.03	< 0.0001	**
Residual	0.1056	5	0.0211			
Lack of Fit	0.0989	3	0.0330	9.89	0.0932	not significant
Pure Error	0.0067	2	0.0033			
Cor Total	14.88	14				
R- Squared	0.9929					
Adj-Squared	0.9801					

**Significant at 1 % (P<0.01) and *significant at 5% (P<0.05) level of significance.

A two dimensional graph of predicted values vs actual values of alcoholicity was plotted for checking the goodness of fit of the model and it is given in Figure 1. The graph shows a straight line, which indicates the model is fit to the experimental data.

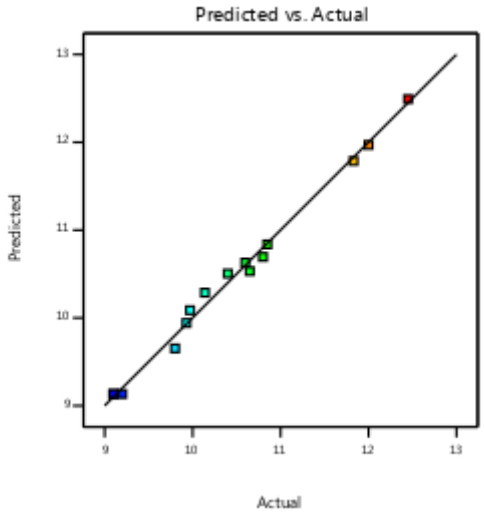

Figure1. The standard curve of Predicted vs Actual values of alcoholicity

Three dimensional response surface plots for the predicted values of alcoholicity (%) for varying levels of yeast, citric acid and diammonia phosphate was drawn and it is given in Figures 2, 3 and 4. It can be inferred from the graphs that the maximum alcoholicity was obtained at highest levels of yeast, diammonium phosphate and central region of citric acid.

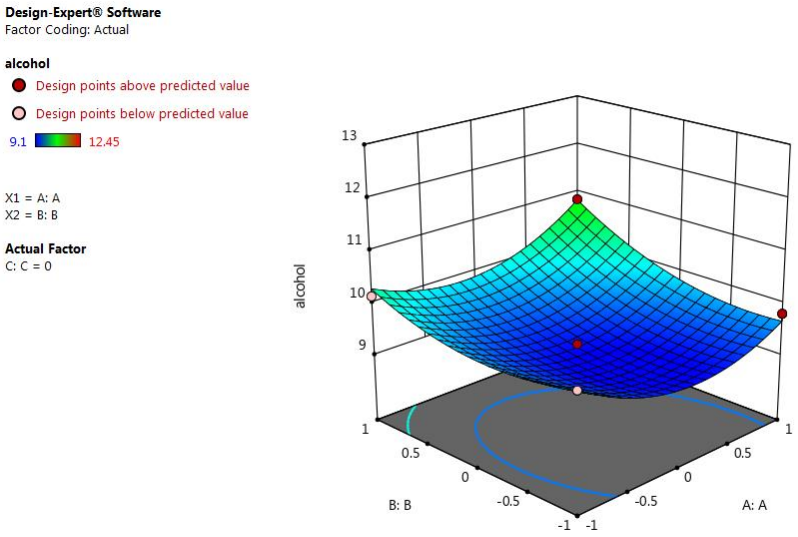

Figure2.Response surface and contour plots for alcoholicity (effect of yeast and citric acid)

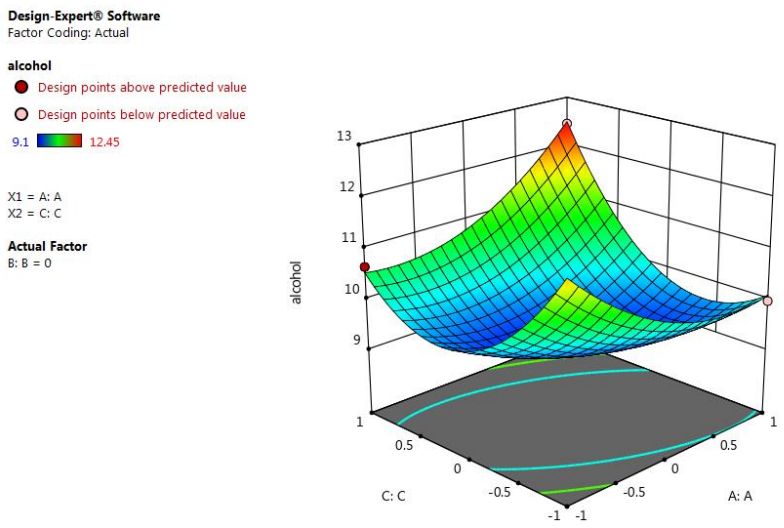

Figure 3.Response surface and contour plots for alcoholicity (effect of yeast and diammonium phosphate)

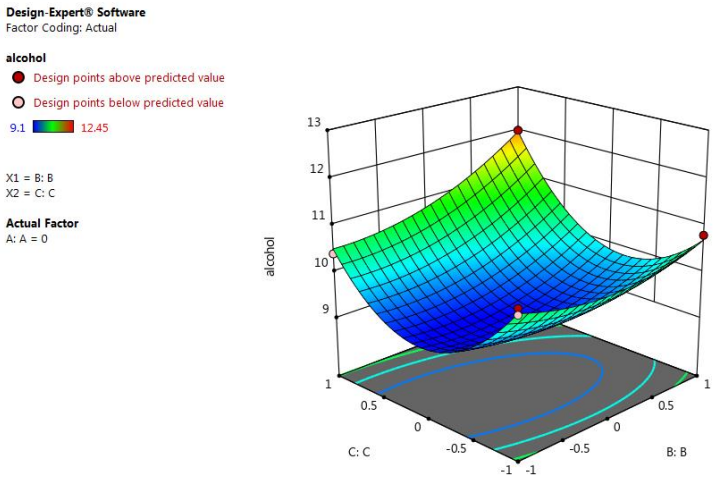

Figure 4.Response surface and contour plots for alcoholicity (effect of citric acid and diammonium phosphate)

Based on the desirability function, the optimum combination was found to be 2.67 % (w/w) 0.4g yeast, 0.55 g citric acid and 0.12g of diammonium phosphate for fermenting 15g of coffee powder. The predicted value of alcoholicity at optimum condition was 12.49% with a desirability score of 1.

Coffee is a highly popular beverage around the globe that boasts a number of impressive health benefits. Caffeine blocks an inhibitory neurotransmitter in our brain which causes a stimulant effect. This improves energy level, mood and various aspects of brain function. Several studies show that caffeine can increase fat burning and boost our metabolic rate. This can also increase adrenaline levels and release fatty acids from our fat tissues. It leads to significant improvements in physical performance. Coffee wine contains antioxidants and it boosts the immune system. It increase bone density and reduces the risk of stroke and type 2 diabetes(www.wideopeneats.com).

Conclusions

Second order response surface model was fitted to optimize fermentation process process conditions viz: yeast, citric acid and diammonium phosphate for the preparation of coffee wine. The experimental data were generated by Box- Behnken design. The model fitted with an R^2value of 0.99, which found to be good for predicting alcoholicity as a function of yeast, citric acid and diammonium phosphate. The optimum condition for the preparation of coffee wine was found to be 0.4gyeast, 0.55g of citric acid and 0.12g of diammonium phosphate.

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