Acta Sci. Pol. Technol. Aliment. 22(1) 2023, 93–102
www.food.actapol.net pISSN 1644-0730 eISSN 1898-9594 http://dx.doi.org/10.17306/J.AFS.2023.1107

ORIGINAL PAPER

Received: 27.11.2022
Accepted: 07.03.2023

STUDY ON PREPARATION TECHNOLOGY FOR MANGO SOUR BEER

Juan Yang✉, Daxiang Li, Xiaojun Hu, Biaoshi Wang, Xiaoshi Zhou, Zihao He, Tao Cheng

Lingnan Normal University
Zhanjiang 524048, **China**

ABSTRACT

Background. Mango sour beer was made from mango and malt. A sensory score was used as an index to study the effects of main fermentation temperature, *Lactobacillus plantarum* addition amount and fermentation tank pressure on the taste of mango sour beer.

Material and methods. Based on the single-factor experiment, a response surface methodology was used to optimize the preparation process of mango sour beer.

Results. The results showed that the optimum fermentation conditions were as follows: the main fermentation temperature was 25°C, the *Lactobacillus plantarum* content was 0.25 kg/KL and the fermenting pressure was 0.15 MPa.

Conclusion. At this point, the mango sour beer was bright and golden, with a clear and transparent body, a rich fruit flavor, an outstanding sour flavor and a mellow wheat flavor, which provides a reference point for the subsequent optimization of the production process and the production of mango sour beer.

Keywords: mango, beer, diastatic fermentation, malt, response surface test

INTRODUCTION

Fruit beer is a kind of beer with a fruit flavor. The ancient Egyptians mentioned the application of jujubes and pomegranates in beer, but it was not until the 1930s that records of fruit beer were found in a few historical documents. Kriek in cherry wine and framboise in wine are the most famous examples of fruit added to beer. Many fruit beers have been revived by the explosion of small breweries in the last 20 years, and fruit wheat wines have become especially popular (Miao et al., 2021; Fanari et al., 2020; Zapata et al., 2019; Ikäheimo, 2020). The various fruits used to brew fruit beers are quite different in terms of both the production process and the flavor of the beer, with some fruits having a substantial and positive effect on the beer and others quite the opposite. Most fruits lose a lot of flavor in the fermentation process, and the strong malt or hops mask the already weak fruit flavor, so the fruit flavor in the finished beer is often difficult to detect.

China's beer production is globally significant, with broad market prospects. People's demand for healthy, tasty and nutritious beer is also increasing (Wang et al., 2020; Huang et al., 2020). There are many types of beer produced in China, but the style is relatively uniform, as fewer varieties of fresh beer are produced by adding fruit. The taste tends to be homogenized, and fresh craft beer with Mango juice to add flavor and nutrition has not been reported. In recent years, China's

✉yang1988dong@163.com

mango planting area has reached 349,000 hectares, with a total output of about 3.3 million tons. The use of mango in food production in China is limited. Mango is one of the most abundant fruits in tropical China and is rich in protein, crude fiber, many vitamins and plant polyphenols, which are useful for vitamin supplementation, cholesterol and triglyceride reduction, antioxidant, anti-aging and hypertension prevention (Zhang et al., 2022; Pu et al., 2022; Chen et al., 2020). Its application in the preparation of mango beer would be one way to make full use of the abundant mango resources in Lingnan, China. However, the fruit beer prepared from mango generally produces a mild flavor and aroma. In the conventional method, the mango-pineapple juice is pasteurized at a higher temperature, which results in significant taste attenuation and serious nutrient loss. Moreover, the product is filtered with diatomite and sterilized again after being canned so that there is no fresh yeast in the product, resulting in significant nutrient loss and a weak taste. In order to solve the problem of the limited application and flavor matching of mango in beer processing in China, a mango sour beer was prepared in this study.

Through the proper pre-treatment of mangoes, the flavor and nutritional value of the fruit can be maintained. Analyzing the fermentation characteristics of mangoes scientifically, matching mangoes with malt, controlling the wort boiling process, and combining the specific saccharification and fermentation processes can effectively retain the sweet and sour sensation of fresh mango in fermented beer and make the mango flavor and wheat aroma blend and coordinate. The obtained mango fresh beer has a rich fruit aroma, a prominent sourness, and a mellow wheat flavor (Ogodo et al., 2018; Lenucci et al., 2022). It effectively retains the nutritional components of mango, such as carotenoids and polyphenols, which have excellent antioxidant properties and health benefits, meeting the demand of contemporary consumers for nutritious fruit-flavored beer.

MATERIALS AND METHODS

Materials and reagents

Mango, Wal-Mart supermarket; Fermented yeast S-33, Fermentis, France; Pale Ale Malt, Castle Malting, Belgium; Wheat malt, Castle Malting, Belgium; Light crystal malt, Castle Malting, Belgium; SorachiAce, BarthHaas (Beijing); Amarillo, BarthHaas (Beijing); *Lactobacillus plantarum*, Xiliang Food Distribution Office, Zhifu District, Yantai; Other reagents are analytically pure.

Fermentation process of mango sour beer

The fermentation process and the main points of each step for mango sour beerare as follows: (1)–(5).

(1) Mashing: The pale ale malt, the wheat malt, and the light crystal malt were crushed in a mass ratio of 200:100:6.5 and mixed with water, and calcium chloride was added to obtain a mash with mixture ratio of 1:3 (kg/L). The pH of the mash was adjusted to 6.0–6.5.

(2) Three-stage saccharification: the mash was first saccharified at 50–53°C for 20–30 min, then saccharified at 62–65°C for 45–60 min, and finally saccharified at 70–72°C for 15–30 min. An iodine test was carried out and, after the test had been passed, the temperature

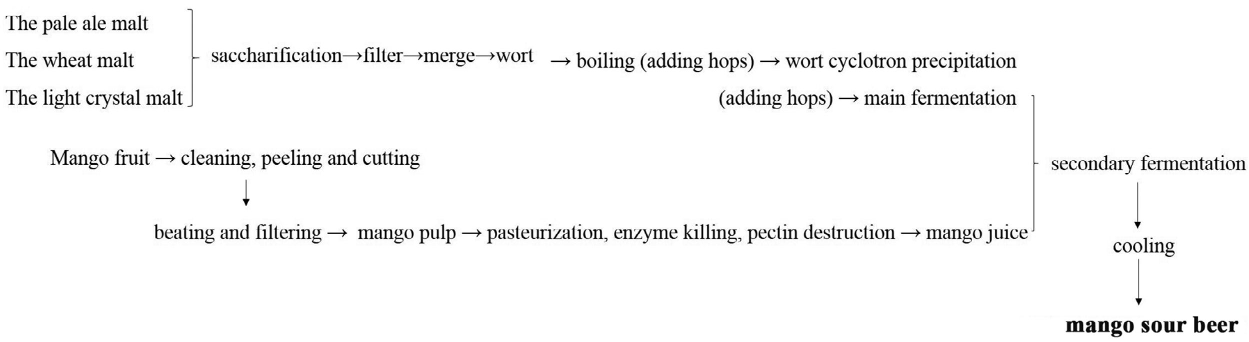

Fig. 1. Fermentation process of mango sour beer

was increased to 76–80°C, filtration and lees washing were carried out, and the filtrate and lees washing water were combined to obtain wort (Mi et al., 2021).

(3) Preparation of mango juice: Fresh mangoes that were ripe, just beginning to soften, free from insects and mold, and full of flesh were selected, cleaned to remove impurities, peeled and cored, cut and pulped to obtain mango pulp. The mango pulp was filtered through 120 mesh filter cloth, heated at 60–65°C for 10–15 min and cooled to get mango juice.

(4) The obtained wort was boiled for 10–15 min, then cooled to 35–39°C. *Lactobacillus plantarum* was added in the amount of 0.2–0.25 kg/KL wort. After maintaining the wort temperature at 35–39°C and lowering the pH to 3.4–3.8, the wort was boiled again for 65–67 min, and hops were added four times during boiling; boil cyclotron precipitation was carried out after boiling.

(5) Fermentation: after cyclotron precipitation, the wort was cooled and oxygenated into the fermenter, then S-33 yeast was added and the main fermentation was carried out at 18–22°C (Shang and Tian, 2021; Meng et al., 2020). When the sugar content of the fermentation liquid dropped to 4.5–5.0°P, mango juice was added and post-fermentation was conducted at 20–22°C. When the pressure in the fermenter rose to 0.14–0.16 MPa and the time reached 1.4–1.8 times the main fermentation time, the temperature of the fermentation liquid was reduced to 5°C for 24 hours. Finally, the fermentation liquid temperature was lowered to 0°C and maintained for 10–14 days after treatment, and the mango sour beer was obtained.

Single-factor test

With the sensory evaluation score as the index, single-factor experiments were conducted according to the following steps (Liu et al., 2021).

(1) *Lactobacillus plantarum* addition: Under the fixed fermentation pressure of 0.15 MPa and fermentation temperature of 20°C, the effects of *Lactobacillus plantarum* addition (0.10 kg/KL, 0.25 kg/KL, 0.40 kg/KL, 0.55 kg/KL, 0.70 kg/KL) on the physicochemical properties and sensory evaluation scores of the finished mango sour beer were investigated.

(2) Fermentation pressure values: Under the conditions of 0.40 kg/KL *Lactobacillus plantarum* addition and 20°C fermentation temperature, the effects of different fermentation pressures (0.05 MPa, 0.10 MPa, 0.15 MPa, 0.20 MPa, 0.25 MPa) on the physicochemical properties and sensory evaluation scores of the finished beer were investigated.

(3) Fermentation temperature values: Under the conditions of *Lactobacillus plantarum* added at 0.40 kg/KL and fermentation pressure of 0.15 MPa, the effects of fermentation temperatures (15°C, 20°C, 25°C, 30°C, 35°C) on the physicochemical properties and sensory evaluation scores of the finished beer were investigated (Ban and Su, 2016).

Response surface experiment

The response surface experiment was conducted with the three selected optimal values of the single-factor test. The three-factor, three-level response surface experiment was designed by Design Expert 8.0.6 software, with the main fermentation temperature (A), *Lactobacillus plantarum* addition (B), and fermenter pressure (C) as the evaluation factors and sensory score (Y) as the response value. The brewing technology used to produce mango sour beer was assessed by establishing a regression equation to predict the maximum response value (Jia et al., 2022). The response surface experiment factors and levels are shown in Table 1.

Table 1. Variables and levels used in Box-Behnken design

Level	Factors		
	A Main fermentation temperature °C	B Addition of *Lactobacillus plantarum* kg/K	C Fermenter pressure MPa
–1	20	0.10	0.10
0	25	0.25	0.15
1	30	0.40	0.20

Sensory evaluation

The evaluation group for sensory evaluation, consisting of 15 people from relevant professions, made sensory ratings of five aspects of mango sour beer – overall impression, aroma, appearance, taste

Table 2. Sensory evaluation methods

Items	Scoring criteria	Score
Overall impression (30 points)	It has a harmonious fruit and wine aroma and has a good and natural taste.	25–30
	It has a relatively harmonious fruit and wine aroma, and the purity of the flavor is slightly defective.	20–24
	The fruit aroma and wine aroma are not harmonious, the fresh feeling of fruit is slightly poor, and the taste is too dry.	<20
Aroma (15 points)	Obvious mango aroma, mellow wheat aroma, no odor.	10–15
	Light mango aroma, plain wheat aroma.	5–9
	No special fruit aroma, prominent alcohol smell.	<5
Appearance (15 points)	It is bright golden yellow and has foggy turbidity, and the foam is white, delicate and lasting.	10–15
	It is golden yellow, and has little suspended impurities, the foam is delicate, not white but lasting.	5–9
	It has uneven color and obvious impurities, and the foam is not white, delicate and durable.	<5
Taste (25 points)	It has an outstanding sour taste and mango flavor, harmonious with malt mellow fragrance, without a peculiar taste.	10–15
	It has a prominent mango flavor and is harmonious with malt mellow fragrance, without a peculiar taste.	5–9
	Its mango flavor is lacking, is not harmonious with the malt mellow fragrance and has a peculiar taste.	<5
Texture (15 points)	The wine is of superior body, pure taste, clean aftertaste and strong taste.	10–15
	The wine is of medium body, pure taste, clean aftertaste and strong taste.	5–9
	The wine is of inferior body and taste. The aftertaste is not clean and the taste is weak.	<5

and texture – with reference to QB/T5476-2020 "General technical requirements for fruit wines." The rating criteria are shown in Table 2.

Determination of alcoholic content

According to the Chinese GB 5009.225-2016 "Determination of ethanol concentration in food national safety standards for wine," first the fermentation fluid was distilled, and then the alcohol content in the fruit beer was determined by the alcohol meter method. The alcoholic content indicated that the volume fraction of ethanol was 20°C.

Determination of the color of raw wort

In accordance with GB/T 4928-2008 "Beer Analysis Method," the degassed specimen was poured into a 25 mm cuvette and then put into the colorimetric box and compared with the standard color plate. The color value was read directly off the colorimetric box when the two hues were the same.

Data processing

Data processing was performed with Design-Expert 8.0.6 for response surface experimental design and analysis. All experiments were repeated three times.

RESULTS AND ANALYSIS

Effect of different main fermentation temperatures on the quality of mango sour beer

The fermentation temperature of the main fermentation was varied from 15°C to 35°C to investigate the effect of the main fermentation temperature on the quality of mango sour beer. The resulting physical and chemical indexes are shown in Table 3.

Table 3. Physical and chemical index determination result

Main fermentation temperature °C	Original wort concentration °P	Alcohol content %vol	Chroma EBC	Bitterness IBU	Sensory score
15	14.2	5.6	8.4	26.6	72.1
20	14.3	5.6	8.5	26.8	78.5
25	14.2	5.5	9.1	27.5	69.2
30	14.1	5.4	9.2	27.7	65.3
35	14.1	5.4	9.3	27.8	62.0

As shown in Table 3, changing the main fermentation temperature changed the sensory evaluation results of the mango sour beer. The fresh beer prepared at the main fermentation temperature of 20°C had a harmonious fruit flavor and mellow wheat aroma, a pure taste, a strong taste, and no peculiar flavor. When the main fermentation temperature was high, it resulted in high advanced alcohol, a rough fat aroma, and a heavy yeast taste.

Effect of different addition amounts of *Lactobacillus plantarum* on the quality of mango sour beer

The amounts of *Lactobacillus plantarum* added to investigate the effect of *Lactobacillus plantarum* addition on the quality of mango sour beer were 0.10 kg/KL, 0.25 kg/KL, 0.40 kg/KL, 0.55 kg/KL and 0.70 kg/KL. The corresponding physical and chemical indexes are shown in Table 4.

From Table 4, it can be seen that the fresh beer prepared with the addition of *Lactobacillus plantarum* at 0.25 kg/KL had a harmonious fruit flavor and mellow wheat aroma, with a fresh mango flavor and a pure taste. The quality of fresh beer changed with the addition of *Lactobacillus plantarum* and adding too little *Lactobacillus* led to low acidification and an imbalance of sweet and sour tastes.

Effect of different fermenter pressures on the quality of mango sour beer

The pressures used in the fermenter to investigate the effect of fermenter pressure on the mango sour beer were 0.05 MPa, 0.10 MPa, 0.15 MPa, 0.20 MPa and 0.25 MPa. The resulting physical and chemical indexes are shown in Table 5.

From Table 5, it can be seen that the fresh beer prepared at a fermenter pressure of 0.15 MPa had a harmonious fruit flavor and mellow wheat aroma, pure taste, strong taste, and the highest sensory score. When the fermenter pressure was too high or too low, the problem of low taste and reduced mellowness was caused by inappropriate fermenter pressure control.

Table 4. Physical and chemical index determination result

Addition of *Lactobacillus plantarum* kg/KL	Original wort concentration °P	Alcohol content %vol	Chroma EBC	Bitterness IBU	Sensory score
0.10	14.0	5.4	9.5	26.7	73.2
0.25	14.3	5.6	8.5	26.8	78.1
0.40	14.4	5.7	8.4	26.9	70.5
0.55	14.4	5.7	8.4	26.9	68.7
0.70	14.5	5.8	8.3	27.1	67.8

Table 5. Physical and chemical index determination result

Fermenter pressure MPa	Original wort concentration °P	Alcohol content %vol	Chroma EBC	Bitterness IBU	Sensory score
0.05	13.8	5.2	8.0	26.7	74.6
0.1	13.9	5.3	8.1	26.8	82.9
0.15	14.3	5.6	8.5	26.8	83.3
0.20	14.4	5.7	8.6	26.9	78.1
0.25	14.4	5.7	8.7	26.9	68.7

Table 6. The design and results of the response surface experiment

No.	A Main fermentation temperature °C	B Addition of *Lactobacillus plantarum* kg/KL	C Fermenter pressure MPa	Y Sensory properties
1	0	0	0	82.70
2	0	1	1	63.90
3	0	0	0	83.10
4	–1	0	–1	70.30
5	1	–1	0	76.90
6	0	–1	–1	65.20
7	0	–1	1	73.00
8	–1	0	1	74.90
9	0	1	–1	76.60
10	0	0	0	83.50
11	1	0	–1	77.90
12	1	0	1	68.50
13	0	0	0	83.00
14	0	0	0	83.90
15	–1	–1	0	67.60
16	1	1	0	67.30
17	–1	1	0	74.40

Response surface experiment design results and regression analysis

Based on the Box-Behnken experimental design and the single-factor test, the analysis was conducted using Design Expert 8.0.6 software (Li et al., 2021). The main fermentation temperature (A), *Lactobacillus plantarum* addition (B) and fermenter pressure (C) were selected as the response factors, and the sensory score (Y) was used as the response value. The response surface analysis was adapted to optimize them. The experimental results are shown in Table 6.

Model building and test of significance

The experimental data were processed using Design Expert 8.0.6 software, and the final quadratic multiple regression equation was $Y = 83.24 + 0.42A - 0.063B - 1.21C - 4.10AB - 3.50AC - 5.12BC - 4.23A^2 - 7.46B^2 - 6.11C^2$. Variance analysis on the data in Table 7 was conducted by Design Expert 8.0.6 software, and the results are shown in Table 7.

Interaction analysis of response surface

The contour lines made by Design Expert 8.0.6 software can be utilized to find out whether the interaction between each test factor was significant and to determine the optimal range of the test factors. The response surface image of the interaction of each factor is shown in Figs 2–4. The image shape of the response surface reflects the strength of the interaction between the two factors. The effects of the factors on the response values are visualized in the response surface images. The response surface images and ANOVA show that the relative magnitudes of the effects of the three factors on the sensory evaluation of

Table 7. Variance analysis of response surface method

Model item	Quadratic sum	DOF	Mean square	F-value	*P*-value	Significant
Model	752.39	9	83.60	137.71	<0.0001	**
A. Main fermentation temperature	1.45	1	1.45	2.38	0.1668	
B. Addition of *Lactobacillus plantarum*	0.031	1	0.031	0.051	0.8270	
C. Fermenter pressure	11.76	1	11.76	19.37	0.0032	*
AB	67.24	1	67.24	110.76	<0.0001	**
AC	49.00	1	49.00	80.72	<0.0001	**
BC	105.06	1	105.06	173.06	<0.0001	**
A^2	75.43	1	75.43	124.25	<0.0001	**
B^2	234.17	1	234.17	385.73	<0.0001	**
C^2	157.06	1	157.06	258.72	<0.0001	**
Residual error	4.25	7	0.61			
Lack of fit	3.38	3	1.13	5.16	0.0733	Non-significant
Error	0.87	4	0.22			
SUM	756.64	16				

Note: $P < 0.05$, indicating a significant difference, is indicated by *; $P < 0.01$, indicating a highly significant difference, is indicated by **.

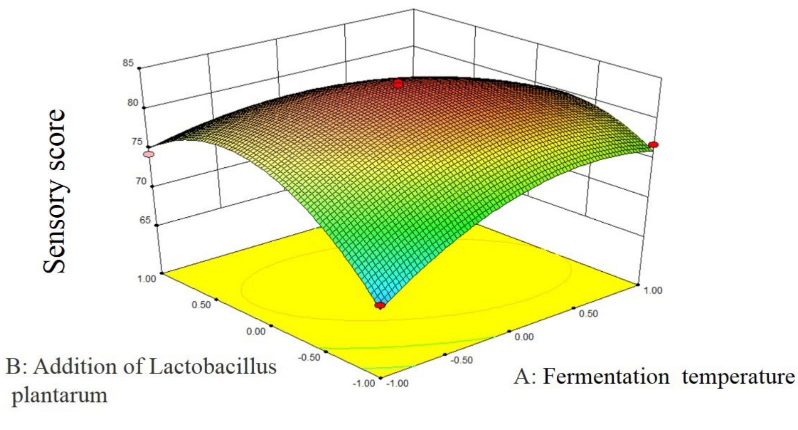

Fig. 2. Effects of main fermentation temperature and *Lactobacillus plantarum* supplementation on sensory score

mango sour beer exhibited the following relationship: fermenter pressure > main fermentation temperature > *Lactobacillus plantarum* addition.

Figure 2 shows the interaction between main fermentation temperature and *Lactobacillus plantarum* addition. Specifically, when the main fermentation

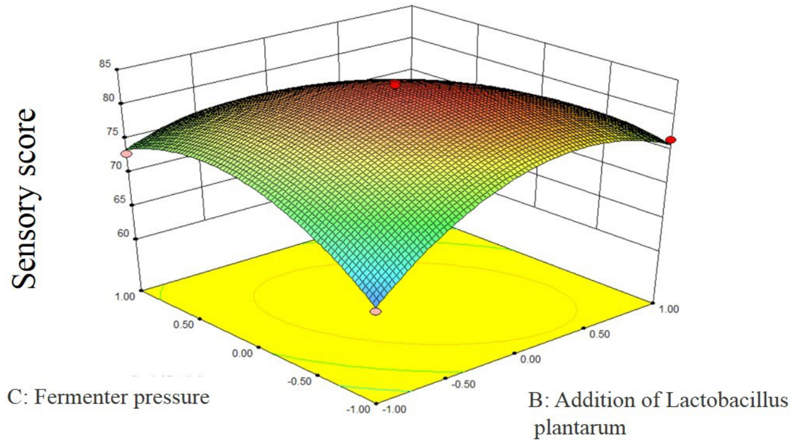

Fig. 3. Effects of interaction of main fermentation temperature and fermenter pressure on sensory score

temperature was fixed, the sensory score increased and then decreased with the increase of *Lactobacillus plantarum* addition. Figure 3 shows the interaction between the main fermentation temperature and fermenter pressure. Specifically, when the fermenter pressure was low, the sensory score increased with main fermentation temperature. However, when the fermenter pressure was high, the sensory score increased first and then decreased with the increase in the main fermentation temperature. Fig. 4 shows the interaction of *Lactobacillus plantarum* addition and fermenter pressure. By solving the equations of the regression model, it was concluded that the response value for production of mango sour beer was maximally 83.34 points with a main fermentation temperature of 25.49°C, *Lactobacillus plantarum* addition of 0.25 kg/KL, and fermenter pressure of 0.14 MPa.

W2s Validation of regression model

The optimized process parameters, main fermentation temperature 25.49°C, *Lactobacillus plantarum* addition 0.25 kg/KL, and fermenter pressure 0.14 MPa,

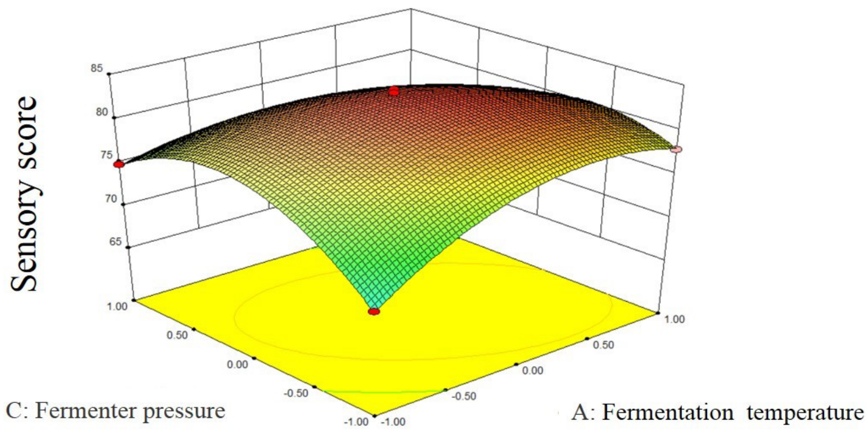

Fig. 4. Effects of interaction between *Lactobacillus plantarum* supplemental level and fermentation tank pressure on sensory score

were obtained from this regression equation. To verify the predictability of the model, and considering what was feasible in actual operation, the process conditions were adjusted to a main fermentation temperature of 25°C, addition of *Lactobacillus plantarum* at 0.25 kg/KL, and a fermenter pressure of 0.15 MPa (Anderson et al., 2019; Nardini and Garaguso, 2020). Under these conditions, three parallel tests were conducted to assess the production process of mango sour beer. The mean sensory evaluation score was 83 ±0.21, which was similar to the predicted value, so the regression model for optimizing the mango sour beer production process using the response surface method was feasible.

CONCLUSIONS AND DISCUSSIONS

In this study, the fermentation process of sour mango fresh beer was optimized on the basis of a single-factor experiment combined with response surface analysis. The optimized process parameters for the fermentation of sour mango fresh beer were a main fermentation temperature of 25°C, addition of *Lactobacillus plantarum* at 0.25 kg/KL, and a fermenter pressure of 0.15 MPa. Under these process conditions, the average sensory score of sour mango fresh beer was 83 ±0.21. The sour mango fresh beer was bright golden yellow in color, with a clear and transparent body, a rich fruit aroma, prominent sourness and a mellow wheat flavor. With these parameters, the fermentation process effectively preserved the sweet and sour taste of mango in the beer and harmonized the mango flavor with the wheat aroma. Moreover, it effectively preserved most of the nutritional components of mango with antioxidant effects. This study not only developed a nutritious fruit beer, but also obtained better process parameters for the production of sour mango fresh beer.

There is a broad market for beer in China, but part of the market is for fruit-flavored beer – that is, beer with added fruit flavor. This kind of beer only satisfies the sensory needs of consumers, and the products do not have the rich nutritional value of fruit. The production and processing of mango fruit beer in this study can alleviate the problem of unsalable fruit. In this study, by analyzing the fermentation characteristics of mango and controlling the boiling process of wort and the saccharification and fermentation processes, the sweet and sour taste of fresh mango in fermented beer was preserved, and the mango flavor and wheat flavor were integrated and coordinated. The control of the preparation cycle and the adjustment of flavor will be the subject of future investigations.

ACKNOWLEDGMENT

The work was supported by the innovation and Entrepreneurship Training Program for College Students (202210579013X).

ETHICS

The authors declare their responsibility for any ethical issues that may arise after the publication of this manuscript.

CONFLICT OF INTEREST

The authors declare that they have no competing interests. The corresponding author affirms that all of the authors have read and approved the manuscript.

REFERENCES

Anderson, H. E., Santos, I. C., Hildenbrand, Z. L., Schug, K. A. (2019). A review of the analytical methods used for beer ingredient and finished product analysis and quality control. Anal. Chim. Acta, 1085, 1–20. https://doi.org/10.1016/j.aca.2019.07.061

Ban Y. D., Su, S. L. (2016). Study on processing technology of compound fermentation fruit wine of mango and tomato. Times Agricultural Machinery, 43(6), 140–141+147.

Chen Y. Y., Dang Z. G., Lin, D., Hu, M. J., Huang, J. F., …, Huang, Y. Y. (2020). Mango scientific research in China in the past 70 years. Chin. J. Trop. Crops, 41(10), 2034–2044. https://doi.org/10.3969/j.issn.1000-2561.2020.10.010

Fanari, M., Forteschi, M., Sanna, M., Piu, P. P., Porcu, M. C., D'hallewin, G., Pretti, L. (2020). Pilot plant production of craft fruit beer using Ohmic-treated fruit puree. J. Food Proc. Preserv., 44(2), e14339. https://doi.org/10.1111/jfpp.14339

Huang, L., Ge X. Q., Zhang, Y. F., Wang, S., Wang, N., Liu, Y. H., Zhang C. Z. (2020). Research progress of special malts for craft beers. China Brewing, 39(2), 7–12. https://doi.org/10.11882/j.issn.0254-5071.2020.02.002

Ikäheimo, J. (2020). Exclusive craft beer events: liminoid spaces of performative craft consumption. Food Cult. Soc., 23(3), 296–314. https://doi.org/10.1080/15528014.2020.1741065

Jia J. H., Chai, H. Y., Cheng, G. L., Cai, Z. J., Zhang, H. T., Tian, X. L., Liang, W. Z. (2022). Optimization of fermentation technology of acanthopanax senticosus wine by response surface methodology. Food Res. Dev., 43(4), 136–142. https://doi.org/10.12161/j.issn.1005-6521.2022.04.020

Lenucci, M. S., Tornese, R., Mita, G., Durante, M. (2022). Bioactive compounds and antioxidant activities in different fractions of mango fruits. Antioxidants, 11(3), 484. https://doi.org/10.3390/antiox11030484

Li, Y., Jiang, X., Huang, J., Dong, X. L., Liu, T. J., Song Y. (2021). Response surface methodology to optimize the brewing process of Rosa roxbunghii craft beer. Food Ind., 42(4), 170–174.

Liu, L.T., Wang, Y.F., Zhao, C.C., Tao, L., Tian, Y. (2021). Optimization of fermentation process of grape seed and passion fruit beer. China Brewing, 40(11), 209–216. https://doi.org/10.11882/j.issn.0254-5071.2021.11.038

Meng, J. M., Fan, A.P., He, C.Q., Zeng, L.P. (2020). Dynamic changes of physicochemical and aroma components in the fermentation process of mango-carrot compound fruit wine. Sci. Technol. Food Ind., 41(12), 7–13. https://doi.org/10.13386/j.issn1002-0306.2020.12.002

Mi, Z., Wu, X. H., Liu, L. Z. (2021). Optimization of beer saccharification technology by orthogonal test. Food Ind., 42(2), 122–125.

Miao, Y. L., Gong, S. M., Zhang, Z. X., Xiao, Y. T., Wang K., Zhao, L., Hu, Z. Y. (2021). Physicochemical properties and antioxidant activity analysis of craft beers brewed by different litchi varieties. Food and Fermentation Industries, 47(13), 174–179. https://doi.org/10.13995/j.cnki.11-1802/ts.026699

Nardini, M., Garaguso, I. (2020). Characterization of bioactive compounds and antioxidant activity of fruit beers. Food Chem., 305, 125437. https://doi.org/10.1016/j.foodchem.2019.125437

Ogodo, A. C., Ugbogu, O. C., Agwaranze, D. I., Ezeonu, N. G. (2018). Production and Evaluation of Fruit Wine from Mangifera indica (cv. Peter). Applied Microbiology: Open Access, 4(1), 1000144. https://doi.org/10.4172/2471-9315.1000144

Pu, H. M., Wang, H. D., Yang, F., Shuai L., Yu, L. J, Li, X. R., Li, H. (2022). Comparison of Preservation Effects of Different Pretreatments on Mango. Mod. Food Sci. Technol., 38(1), 197–205. https://doi.org/10.13982/j.mfst.1673-9078.2022.1.0449

Shang, Y. H., Tian, J. F. (2021). Optimization of fermentation process and determination of component contents of mango and apple compound wine. China Brewing, 40(6), 13, 235–140. https://doi.org/10.11882/j.issn.0254-5071.2021.06.026

Wang L., Xue Y. M., Wang, J., Ban Y. J., Wang Q. Q., Luo J., Liu J. Y., Zhang W. Q. (2020). The status and development of china craft beer. Mod. Food, (14), 18–20. https://doi.org/10.16736/j.cnki.cn41-1434/ts.2020.14.006

Zhang, M. J., Zhang, J. H., Zhang, Y. J., Yang, J. (2022). Climaticg suitability regionalization of mango cultivation in China. Jiangsu Agric. Sci., 50(2), 124–130. https://doi.org/10.15889/j.issn.1002-1302.2022.02.021

Zapata, P. J., Martínez-Esplá, A., Gironés-Vilaplana, A., Santos-Lax, D., Noguera-Artiaga, L., Carbonell-Barrachina, Á. A. (2019). Phenolic, volatile, and sensory profiles of beer enriched by macerating quince fruits. LWT, 103, 139–146. https://doi.org/10.1016/j.lwt.2019.01.002