Optimization of brandy base wine production technique using ginger pomace

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Abstract: In this work, the effects of ginger pomace/water ratio, yeast strain selection, sugar and yeast addition, fermentation temperature on the physicochemical properties and sensory evaluation of ginger brandy and its base wine was investigated to optimize production technique. It was found that the pH and total acidity of ginger brandy base wine were mainly influenced by ginger pomace/water ratio, yeast strain, sugar and yeast addition, fermentation temperature. Gingerol content was mostly affected by ginger pomace/water ratio. The results of electronic nose analysis showed that main aroma components of ginger pomace brandy were mainly affected by ginger pomace/water ratio. In general, the optimized production technique was ginger pomace/water ratio at 1:3, 3# yeast strain, sugar and yeast addition (102 g/L and 0.40 g/L), fermentation temperature (18℃). Ginger brandy base wine made by above technique after second full distillation could produce ginger brandy with typical, strong and balanced ginger aroma, mellow and full-bodied taste, and long aftertaste.

1 INTRODUCTION

China is the main country of ginger production in the world, rich in resources, with a total planting area of 285,300 hm^2. The production from 2016 to 2020 are 9,380,000, 8,930,000, 8,460,000, 7,620,000 and 9,190,000 tons, respectively [1]. Ginger is a medicinal and edible plant that originated in Southeast Asia and has been cultivated for thousands of years [2]. Ginger contains 3%-6% fat, 9% protein, 60%-70% carbohydrate, 3%-8% crude fiber, 9%-12% water, and 2%-3% volatile oil [3]. In addition to edible nutrition, it also has medicinal ingredients such as gingerol, polysaccharides, etc [4]. Gingerol is the main medicinal component of ginger and has a wide variety, mainly including zingiberone, 6-gingerol, 6-shogaol, 8-gingerol, and 10-gingero l[5]. According to previous study, 6-gingerol has a therapeutic effect on LTA-induced mastitis. When the concentration of 6-gingerol is 20 μM, it can significantly reduce inflammatory cells, cytokines and reactive oxygen species, promote the proliferation of glandular cells, and reduce the damage to the breast [6]. At present, ginger extract has been successfully used in lowering blood sugar [7], anti-inflammatory [8], anti-cancer [9], and antioxidant [10]. These medicinal effects can increase the value of ginger.

As a condiment, ginger has a special aroma. Huang et al. identified 60 volatile components from dried ginger using GC-MS, including zingiberene (26.4%-37.1%), β-phellandrene (7.4%-12.9%), β-sesquiphellandrene (10.2%-12.8%), and geranial (6.6%-8.1%) [11]. Due to its

rich nutrition and aroma, ginger has been made into various products, such as ginger juice, tea and preserved ginger. At present, most ginger products are made with ginger juice. The by-product of ginger juice, ginger pomace, contains various active ingredients, such as ginger essential oil, gingerol, and dietary fiber. This study intends to use ginger pomace to make a ginger pomace brandy with typical, strong ginger aroma and balanced taste. In our study, the effects of ginger pomace/water ratio, yeast strain selection, sugar and yeast addition, fermentation temperature on the physicochemical properties and sensory evaluation of ginger brandies and its base wine was investigated to optimize their production technique.

2 MATERIALS AND METHODS

2.1 Materials

Ginger pomace purchased from Yijiakang Food Company (Qingzhou, Shandong), sugar purchased from the local market (Taian, Shandong), Saccharomyces cereviaiae, purchased from Lallemand Company (Toulouse France) were labeled as 1#, 2#, 4#, 5#, another one purchased from Eaton (Langenlonshein Germany) was labeled as 3#.

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2.2 Experimental methods

2.2.1 Preparation of ginger pomace base wine and brandy
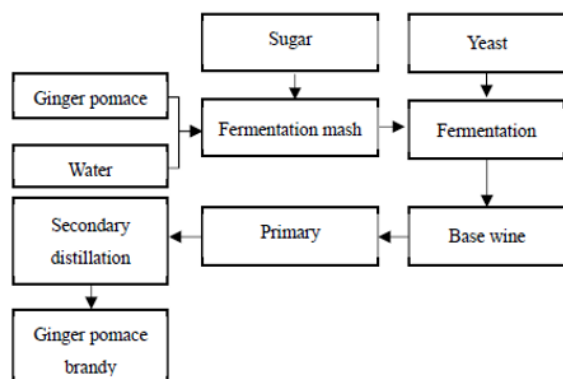
2.2.2 Selection method of optimum ginger pomace/water ratio

Fermention mash was prepared according to ginger pomace/water ratio =1:1, 1:2, 1:3, 1:4, 1:5, respectively. The sugar content was adjusted to 102 g/L, and yeast was inoculated at 0.4 g/L, and fermented at 20°C. The total sugar, reducing sugar, alcohol content, pH and total acidity of five base wines were determined, and the alcohol content, total acid, total ester and volatile acids of five kinds of brandies were determined. The sensory quality was analyzed and evaluated. The highest sensory score was selected as the best ginger pomace/water ratio.

2.2.3 Selection method of the best yeast strain

1#, 2#, 3#, 4# and 5# yeasts were added to fermention mash, respectively, under the optimum conditions of ginger pomace/water ratio. The sugar content was adjusted to 102 g/L, The yeast addition was 0.4 g/L, and the fermentation temperature was 20°C. The same indexes of the five base wines and brandies were done as 2.2.2. The highest sensory score was selected as the most suitable yeast strain.

2.2.4 Determination of optimum sugar content in fermentation mash

Under the optimum conditions of ginger pomace/water ratio, the sugar content of fermentation mash was adjusted to 85 g/L, 102 g/L, 119 g/L, 136 g/L and 153 g/L, respectively, and the most suitable yeast strain was used.

The same indexes analysis was done as 2.2.2 of the base wine and brandy. The highest sensory score was selected as the most suitable sugar content.

2.2.5 Determination of optimum yeast addition

Under the optimum conditions of ginger pomace/water ratio, the most suitable yeast strain and sugar content were added to the fermentation mash. And the addition of yeast was adjusted to 0.25 g/L, 0.3 g/L, 0.35 g/L, 0.4 g/L, 0.45 g/L, respectively, The fermentation temperature was 20°C. Then the same indexes analysis was done as 2.2.2. The highest sensory score was selected as the most suitable yeast addition.

2.2.6 Determination of optimum fermentation temperature of base wine

Under the optimum conditions of ginger pomace/water ratio, the most suitable yeast strain , sugar content, and yeast addition were added to the fermention mash. And the fermention mash was fermented at 16°C, 18°C, 20°C, 22°C and 24°C respectively. The same indexes of the five base wines and brandies were done as 2.2.2. The highest sensory score was the best fermentation temperature.

2.3 Analysis method

2.3.1 Determination of physicochemical indexes of ginger pomace base wine and brandy

The determination methods of alcohol content, total sugar, total acidity and pH of ginger pomace base wine were according to GB/T15038-2006 *General analysis method for wine and fruit wine*. The determination methods of precision, total acidity, total ester and volatile acids of ginger pomace brandy wine were according to GB/T11856-2008 *Brandy*.

2.3.2 Electronic nose measurement method

Electronic nose measurement method were according to Adelina's method[12] with slight modifications. 1mL of ginger pomace brandy was diluted five times and added to 25 mL headspace bottle, stilled at 20°Cfor 20 minutes, and then determined. Each sample was measured three parallel.

2.3.3 Sensory evaluation and Rank-rating

Sensory evaluation was according to GB/T 10220 *Summary of sensory analysis methodology* and GB/T 11856-2008 *Brandy*, and detailed assessment was shown in Table 1.

Table 1. Sensory evaluation standard of Ginger pomace brandy

	Sensory evaluation
Appearance（10′）	Whether the appearance was colorless, clear and shiny, without sundries, turbidity
Aroma（30′）	Whether there was a harmonious aroma of ginger, whether the various aromas were coordinated and elegant, whether there was a smell of irritation.

Taste （40′）	Whether the taste was sweet, mellow, delicate, full, continuous, harmonious, Whether the ginger spicy taste was heavy, suitable or insufficient, whether there was a miscellaneous flavor
Typical （20′）	Whether the ginger pomace brandy was unique style, typical.

Sensory evaluation method: five samples were sent to 11 qualified cuppers in random order, and the cuppers were asked to evaluate the appearance, aroma, taste and typicality of the samples according to Table 1.

Rank-rating was represented accoding to the sensory score as well as the quality of the five samples. By sorting, the rank sum and T value were calculated. The significant difference between different samples was obtained by comparing with the critical value Table of Friedman test[13] and the LSRD[13] value of Fishers[13]. And the samples with low rank sum were more favored by the cuppers.

2.4 Statistical analysis.

The experimental data were analyzed by Excel 2016 and IBM SPSS Statistics 25. Each experiment was paralleled three times and the results were expressed as mean ± standard deviation and different letters in each row mean significant difference (p＜0.05).

3 RESULTS AND DISCUSSIONS

3.1 Effects of ginger pomace/water ratio on the physicochemical properties and sensory evaluation of ginger brandy and its base wine

3.1.1 Effects of ginger pomace/water ratio on the physicochemical properties of ginger brandy and its base wine

Physicochemical properties of ginger pomace brandy and its base wine with five different ginger pomace/water ratios were shown in Table 2. The ginger pomace/water ratio affected the pH and total acid of ginger pomace brandy base wine. The pH of the base wine had the same change trend as the total acidity. As ginger pomace/water ratio increased, the total acidity decreased and the pH increased. When ginger pomace/water ratio at 1:5, the highest pH was 3.67, and the lowest total acidity was 5.64 g/L. Ginger pomace/water ratio also had an important effect on the gingerol content, when ginger pomace/water ratio increased, gingerol content decreased significantly. The total acidity of ginger pomace brandy correlated well with its base wine (r=0.889, p<0.05). After alcohol contents of the brandy were adjusted to the same level, when ginger pomace/water ratio was at 1:1, when ginger pomace/water ratio was at 1:5, the highest total acidity and ester were 0.25 g/L and 0.95 g/L, respectively. The lowest total acidity and esters content was 0.22 g/L and 0.93 g/L, respectively. Total ester, total acidity and volatile acids decreased with the increasing of ginger pomace/water ratio.

3.1.2 Principal component analysis of ginger pomace brandy with different ginger pomace/water ratios by using electronic nose

Principal component analysis of ginger pomace brandy with different ginger pomace/water ratios by using electronic nose was presented in the Figure 1. The contribution rate of the first principal component (PC1)

Table 2 Physicochemical properties of ginger pomace brandy and its base wine with different ginger pomace/water ratio

		Ginger pomace/water ratio				
		1:1	1:2	1:3	1:4	1:5
Base wine	Alcohol content (%)	6.03±0.01e	6.52±0.00a	6.23±0.00d	6.33±0.00c	6.36±0.00b
	pH	3.33	3.51	3.34	3.88	3.67
	Reducing Sugar (g/L)	0.53±0.01b	0.50±0.00c	0.45±0.00d	0.43±0.00e	0.60±0.00a
	Total Sugar (g/L)	0.59±0.01b	0.51±0.00c	0.51±0.00d	0.50±0.00e	0.74±0.00a
	Total Acidity (g/L)	7.35±0.01a	6.31±0.00c	6.58±0.00b	5.98±0.00d	5.64±0.00e
	Gingerol (mg/L)	56.27±0.00a	49.73±0.03b	35.43±0.03c	30.88±0.00d	28.92±0.03e
Brandy	Alcohol content (%)	35	35	35	35	35
	Total Acidity (g/L)	0.25±0.002a	0.24±0.002a	0.23±0.000b	0.22±0.002bc	0.22±0.002c
	Total ester (g/L)	0.95±0.002a	0.93±0.002d	0.94±0.001b	0.93±0.001c	0.93±0.003cd
	Volatile acids (g/L)	0.07±0.001a	0.07±0.000a	0.06±0.001a	0.06±0.000b	0.05±0.000c

was 96.037%, while the contribution rate of the second principal component (PC2) was 1.8721%, and the total contribution rate of PC1 and PC2 was 99.909%, which was much higher than 85%. The two principal components could represent the main volatile components of ginger

pomace brandy. From the PCA load diagram, it was found that the five samples were separated from each other and there was no overlap, and it indicated that the aroma of the five ginger pomace brandies had a relatively obvious difference, and ginger pomace/water ratio had a great
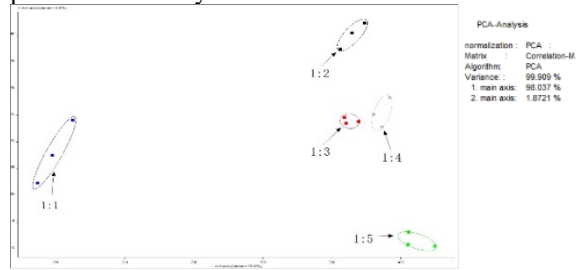
impact on the brandy aroma.

Figure 1. PCA load diagram of electronic nose analysis for ginger pomace brandy with different ginger pomace/water ratios

3.1.3 Sensory evaluation of ginger pomace brandy with different ginger pomace/water ratios

Sensory evaluation of ginger pomace brandy with five ginger pomace/water ratios was shown in Figure 2. Because of full distillation, ginger pomace brandies with ginger pomace/water ratios at 1:4 and 1:5 had obvious milky white turbidity, consequently these 2 brandies got low appearance scores. From the perspective of aroma, brandy with ginger pomace/water ratios at 1:1 and 1:3 had the highest scores while the brandy with ginger pomace/water ratios at 1:4 got the lowest score. For the taste, the brandy with ginger pomace/water ratios at 1:3

got the highest score while the brandy with ginger pomace/water ratios at 1:5 tasted flat and got the lowest score. For the typicality, all these five brandies had typical ginger flavor and got 100%. In general, brandy with ginger pomace/water ratios at 1:3 had typical ginger aroma, balanced wine flavor, smooth taste, and proper gingerol strength, consequently, got the highest score.
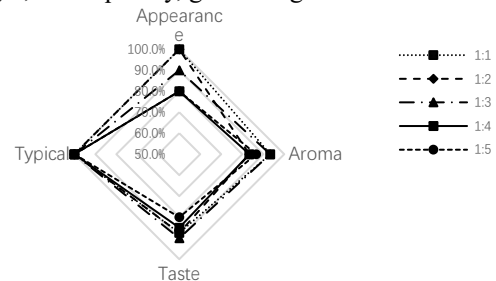

Figure 2. Radar chart of sensory score of ginger pomace brandy with different ginger pomace/water ratios

Ranking results and significant difference of the five sample were shown in Table 3. There was a significant difference between ginger pomace/water ratios at 1:5 and others. Through the sum of ranks, it could be concluded that ginger pomace brandy with fermentation temperature at 18°C was the most popular.

Table 3. Quality ranking results of five different ginger pomace/water ratios of ginger brandy by 11 qualified cuppers

Cuppers	Ginger pomace/water ratios				
	1:1	1:2	1:3	1:4	1:5
1	2	3	1	4	5
2	3	1	2	4	5
3	3	2	1	4	5
4	4	2	1	3	5
5	5	4	2	1	3
6	3	4	1	2	5
7	4	3	2	1	5
8	3	5	1	2	4
9	3	2	1	5	4
10	3	4	2	1	5
11	2	3	1	4	5
Sum of ranks	35	33	15	31	51
Significance	B	B	C	B	A

3.2 Effects of different yeast stains on the physicochemical properties and sensory evaluation of ginger brandy and its base wine

3.2.1 Effects of different yeast stains on the physicochemical properties of ginger brandy and its base wine

The physicochemical properties of ginger brandy base wines made by five different yeast strains were shown in Table 4. In terms of alcohol content, 3# yeast could produce base wine with the highest alcohol content at 6.12 g/L, and 1# yeast could produce base wine with the highest pH at 3.35 and the highest total acid content at 6.75 g/L. In terms of total sugar and reducing sugar, 5# yeast could produce base wine with the highest total sugar and reducing sugar at 3.83 g/L and 3.11 g/L, respectively. Gingerol contents in five samples were different, but the

effect of different yeast strains on gingerol contents was lower than that of ginger pomace/water ratio. It was due to that the gingerol contents was mainly related to the ginger itself. After second distillation and the alcohol content of ginger pomace brandy was adjusted to 27%, the 5# yeast strain could produce brandy with highest total acidity at 0.43 g/L, while the 5# yeast strain had the lowest at 0.89 g/L. Furthermore, the 1# yeast strain had the highest volatile acid content at 0.10 g/L and 3# and 4# yeast strains shared the lowest at 0.06 g/L.

3.2.2 Principal component analysis of ginger pomace brandy with different yeast strains by using electronic nose
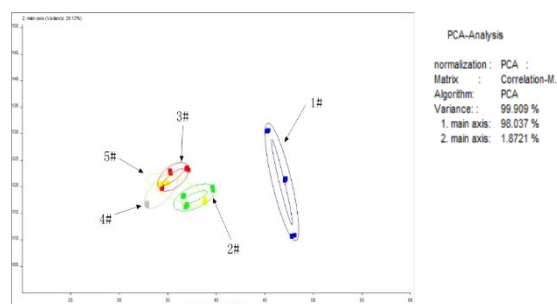

Figure 3. PCA load diagram of ginger pomace brandy electronic nose with different yeast strains

Principal component analysis of ginger pomace brandy with different yeast strains by using electronic nose was presented in the Figure 3. The contribution rate of the first principal component (PC1) was 98.037%, while the contribution rate of the second principal component (PC2) was 1.87217%, and the total contribution rate was 99.909%, which was much higher than 85%. The two principal components could represent the main volatile components of ginger pomace brandy. From the PCA load diagram, it was found that there was a significant distance between 1# yeast and the other four yeast strains. The aromas of 2#, 3#, 4#, and 5# were relatively close and their PCA load diagram were partial overlapped, indicating that these 4 ginger pomace brandies were similar in aroma.

3.2.3 Sensory evaluation of ginger pomace brandy with different yeast strains
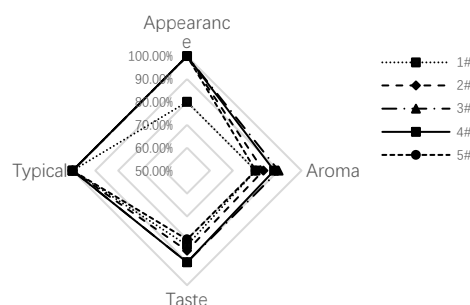

Figure 4 Radar chart of sensory score of ginger pomace brandy with different yeast strains

Table 4 Physicochemical properties of ginger pomace brandy and its base wine with different yeast strains

		Yeast strains				
		1#	2#	3#	4#	5#
Base wine	Alcohol content (%)	6.01±0.00c	6.04±0.00b	6.12±0.00a	5.95±0.01d	5.92±0.02e
	pH	3.35	3.33	3.34	3.34	3.32
	Reducing Sugar (g/L)	3.11±0.00a	2.95±0.00b	2.84±0.01c	2.51±0.01e	2.79±0.01d
	Total Sugar (g/L)	3.83±0.01b	3.41±0.01c	3.17±0.00d	3.06±0.00e	4.58±0.0a
	Total Acidity (g/L)	6.75±0.04a	5.87±0.04c	5.72±0.00d	5.73±0.00d	6.18±0.00b
	gingerol (mg/L)	40.35±0.03a	38.59±0.00d	38.96±0.05c	39.58±0.00b	38.12±0.03e
Brandy	Alcohol content (%)	27	27	27	27	27
	Total Acidity (g/L)	0.35±0.007b	0.32±0.002c	0.30±0.003d	0.27±0.003e	0.43±0.014a
	Total ester (g/L)	1.09±0.039b	0.95±0.002c	0.95±0.003c	0.89±0.034d	1.12±0.003a
	Volatile acids (g/L)	0.10±0.001a	0.07±0.000c	0.06±0.001d	0.06±0.004d	0.09±0.000b

Sensory evaluation of ginger pomace brandy with five yeast strains was shown in Figure 4. In general, 1# yeast strain got the lowest appearance score. 3# yeast strain got the highest aroma score while the 1# and 5# scored the lowest. 3# and 4# got the highest taste score. All these five samples had the typical ginger flavor and scored 100%. Overall, ginger pomace brandy with 3# yeast strain was the most popular and got the highest total score with typical ginger flavor, strong and balanced taste, proper gingerol strength.

Table 5. Quality ranking results of five different yeast of ginger brandy by 11 quality cuppers

Cuppers	Different yeast strains				
	1#	2#	3#	4#	5#
1	3	2	1	4	5
2	1	3	2	4	5
3	5	2	1	3	4
4	4	3	1	2	5
5	5	4	2	1	3
6	3	4	1	2	5
7	4	3	2	1	5
8	3	5	1	2	4
9	3	2	1	5	4
10	3	4	2	1	5

11	3	1	2	4	5
Sum of ranks	37	33	16	29	50
Significance	AB	BC	D	C	A

Ranking results and significant difference from the cuppers were shown in Table 5. Through the sum of ranks, it could be concluded that ginger pomace brandy with 3# yeast strains was the most popular.

3.3 Effects of sugar addition on the physicochemical properties and sensory evaluation of ginger brandy and its base wine

3.3.1 Effects of different sugar addition on the physicochemical properties of ginger brandy and its base wine

Physicochemical properties of ginger pomace brandy and its base wine with different sugar addition were shown in Table 6. The alcohol content of base wine changed with different sugar addition. The highest alcohol content was 9.05% with sugar addition of 153 g/L, and the lowest alcohol content was 5.12% with sugar addition of 85 g/L. For the total acidity and pH, when the sugar addition was 85 g/L, the total acidity was highest at 7.75 g/L and pH was lowest at 3.31. By contrast, when the sugar addition was 136 g/L, the total acidity was lowest at 6.72 g/L and pH was highest at 3.35. The total sugar and reducing sugar contents changed greatly. The sugar addition increased, and the reducing sugar and total sugar also increased, which

Table 6. physicochemical properties of ginger brandy and its base wine with different sugar addition

		Different sugar addition(g/L)				
		85	102	119	136	153
Base wine	Alcohol content (%)	5.12±0.00e	6.04±0.00d	7.02±0.01c	7.90±0.01b	9.05±0.00a
	pH	3.31	3.34	3.35	3.35	3.34
	Reducing Sugar (g/L)	1.53±0.03e	2.41±0.01d	3.17±0.00c	4.96±0.01b	5.58±0.03a
	Total Sugar (g/L)	2.23±0.02e	2.80±0.00d	3.67±0.05c	5.17±0.02b	6.18±0.11a
	Total Acidity (g/L)	7.75±0.00a	6.87±0.00c	6.73±0.00d	6.72±0.00d	6.88±0.00b
	gingerol (mg/L)	44.36±0.05b	43.32±0.12c	42.14±0.03e	45.22±0.03a	43.12±0.09d
Brandy	Alcohol content (%)	34	34	34	34	34
	Total Acidity (g/L)	0.37±0.003a	0.36±0.000b	0.32±0.000d	0.31±0.002e	0.35±0.002c
	Total ester (g/L)	1.17±0.008a	0.99±0.002b	0.97±0.001c	0.88±0.001d	0.87±0.003d
	Volatile acid (g/L)	0.11±0.001a	0.09±0.000b	0.08±0.001c	0.06±0.000d	0.06±0.000d

might be related to yeast fermentation. The high sugar addition made the yeast incomplete utilization, and the total sugar and reducing sugar left in the final wine also increased. After alcohol contents of all samples were adjusted to 34%, it could be found that ginger brandy with sugar addition at 85 g/L had the highest total acidity at 0.37 g/L while that with sugar addition at 136 g/L had the lowest total acidity at 0.31 g/L. The total ester of ginger pomace brandy correlates well with volatile acid contents ($r=0.976$, $p<0.01$). The total ester of ginger pomace brandy decreased with the increasing sugar addition. When the sugar addition was 85 g/L, the total ester was highest at 1.17 g/L. On contrary, when the sugar addition was 153 g/L, the total ester was lowest at 0.87 g/L. Besides, when the sugar addition was 85 g/L, the volatile acids were highest at 0.11 g/L.
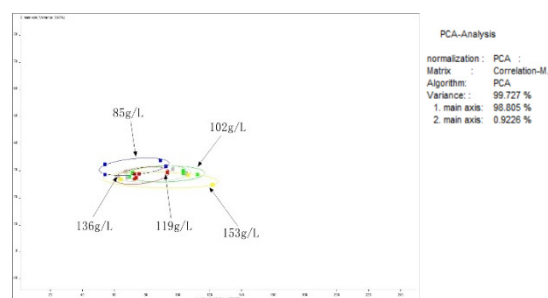

Figure 5. PCA load diagram of ginger pomace brandy electronic nose with different sugar addition

3.3.2 Principal component analysis of ginger pomace brandy with different sugar addition by using electronic nose

Principal component analysis of ginger pomace brandy with different sugar addition by using electronic nose was presented in the Figure 5. The contribution rate of the first principal component (PC1) was 98.805%, while the contribution rate of the second principal component (PC2) was 0.9226%, and and the total contribution rate of PC1 and PC2 was 99.727%, which was much higher than 85%. Besides, it was found that their PCA load diagrams were

overlapped and could not be separated, indicating that these five ginger pomace brandies were similar in aroma. Consequently, it could be concluded that sugar addition had little effect on the aroma of ginger pomace brandy.

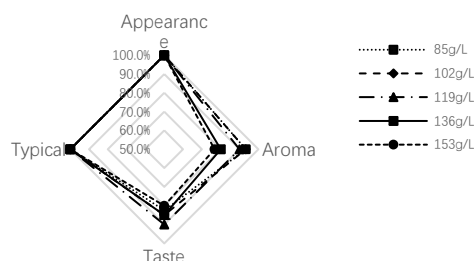### 3.3.3 Sensory evaluation of ginger pomace brandy with different sugar addition

Figure 6. Radar chart of sensory score of ginger pomace brandy with different sugar addition

Sensory evaluation of ginger pomace brandy with five sugar addition was shown in Figure 6. For the aroma, when the alcohol contents of base wine were at 85 g/L and 102 g/L, their corresponding brandies got higher aroma score and higher evaluation. When the alcohol content of base wine was at 153 g/L, corresponding brandy got lowest score. It might be due to that the brandy was concentrated and its aroma was more prominent when the alcohol content of its base wine was low. From the perspective of taste, brandy with 153 g/L sugar addition had the lowest score. The base wine with higher alcohol content concentration could produce higher brandy volume consequently, the brandy had low aroma concentration and flat taste. The brandy with 102 g/L sugar addition had concentrated aroma, strong and balanced taste, proper gingerol strength, and typicity of ginger pomace brandy.

Table 7. quality ranking results of five different sugar addition of ginger brandy by 11 quality cuppers

Cuppers	Sugar addition(g/L)				
	85	102	119	136	153
1	4	1	3	2	5
2	2	1	3	4	5
3	3	1	2	4	5
4	3	2	1	3	5
5	3	1	4	2	5
6	3	2	5	1	4
7	3	4	2	1	5
8	3	2	1	5	4
9	3	1	2	5	4
10	2	3	1	4	5
11	3	2	1	4	5
Sum of ranks	32	20	25	35	52
Significance	B	B	B	B	A

Ranking results and significant difference from the cuppers were shown in Table 7. Through the sum of ranks, it could be concluded that ginger pomace brandy with 102 g/L sugar addition was the most popular.

3.4 Effects of different yeast addition on the physicochemical properties and sensory evaluation of ginger brandy and its base wine

3.4.1 Effects of different yeast addition on the physicochemical properties of ginger brandy and its base wine

The physicochemical properties of ginger brandy base wines with different yeast addition were shown in Table 8. The alcohol contents of various sugar addition were different; the alcohol content was highest at 6.23 g/L when the yeast addition was 0.45 g/L while the alcohol content

was lowest at 5.95 g/L when the yeast addition was 0.25 g/L. With the increasing yeast addition, the total acidity increased, and the pH decreased. The total acidity was highest at 7.85 g/L when the yeast addition was 0.45 g/L while it was lowest at 6.85 g/L when the yeast addition was 0.25 g/L. When the yeast addition was 0.25 g/L, the total sugar and reducing sugar left in the final brandy were highest, which might be due to that the fermentation was restricted by limited yeast addition, leading to low alcohol content production and high total sugar and reducing sugar contents. When the alcohol content of ginger pomace brandy was adjusted to 35% after second distillation and the total acidity of base wine corelates well with total acidity, total ester, and volatile acids of brandy ($p < 0.05$), which increased with the increasing yeast addition. When the yeast addition was 0.45 g/L, the total acidity, total easter, and volatile acids were highest at 0.35 g/L, 1.08 g/L, and 0.15 g/L, respectively. By contrast, when the yeast addition was 0.25 g/L, the total acidity, total easter, and

volatile acids were lowest at 0.31 g/L, 0.94 g/L, and 0.10 g/L, respectively.

Table 8. Physicochemical properties of ginger pomace base wine and ginger pomace brandy with different yeast addition

		Different yeast addition(g/L)				
		0.25	0.30	0.35	0.40	0.45
Base wine	Alcohol content (%)	5.95±0.00e	6.01±0.01d	6.15±0.00b	6.09±0.01c	6.23±0.01a
	pH	3.35	3.30	3.28	3.24	3.24
	Reducing Sugar (g/L)	5.02±0.00a	1.41±0.01e	2.17±0.01d	3.06±0.00b	2.58±0.01c
	Total Sugar (g/L)	5.65±0.02a	1.60±0.00e	2.37±0.01d	3.12±0.01b	2.75±0.01c
	Total Acidity (g/L)	6.85±0.00d	7.08±0.00c	7.33±0.00b	7.80±0.01a	7.85±0.02a
	gingerol (mg/L)	45.26±0.00a	46.32±0.03b	43.23±0.05c	44.30±0.00c	44.85±0.05d
Brandy	Alcohol content (%)	35	35	35	35	35
	Total Acidity (g/L)	0.31±0.002c	0.32±0.002b	0.35±0.002a	0.35±0.000a	0.35±0.002a
	Total ester (g/L)	0.94±0.002d	0.96±0.002c	0.97±0.000b	1.07±0.002a	1.08±0.003a
	Volatile acid (g/L)	0.10±0.001d	0.11±0.010c	0.11±0.010c	0.13±0.000b	0.15±0.000a

3.4.2 Principal component analysis of ginger pomace brandy with different yeast addition by using electronic
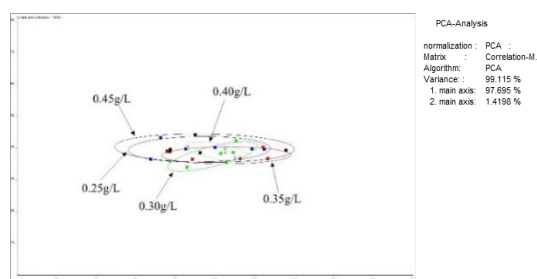

Figure 7. PCA load diagram of ginger pomace brandy electronic nose with different yeast addition

Principal component analysis of ginger pomace brandy with different sugar addition by using electronic nose was presented in the Figure 7. The contribution rate of the first principal component (PC1) was 97.695% while the contribution rate of the second principal component (PC2) was 1.4198%, and the total contribution rate of PC1 and PC2 was 99.115%, which was much higher than 85%. The two principal components could represent the main volatile components of ginger pomace brandy, which meant the results were reliable. Besides, it was found that their PCA load diagrams were overlapped and could not be separated, indicating that these five ginger pomace brandies were similar in aroma. Consequently, it could be concluded that yeast addition had little effect on the aroma of ginger pomace brandy.
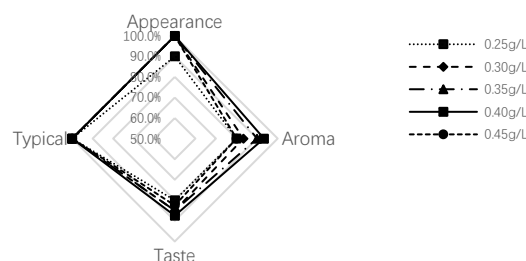

Figure 8. Radar chart of sensory score of ginger pomace brandy with different yeast addition

3.4.3 Sensory evaluation of ginger pomace brandy with different yeast addition

Sensory evaluation of ginger pomace brandy with different yeast addition was shown in Figure 8. In general, brandy with 0.25 g/L yeast addition got the lowest appearance score. Brandies with 0.25 g/L and 0.45 g/L yeast addition got the lowest aroma score while brandy with 0.40 g/L yeast addition got the highest score. For the taste, brandy with 0.40 g/L yeast addition got the highest score while brandy with 0.25 g/L yeast addition got the lowest score. All these five samples had the typical ginger flavor and scored 100%. Overall, ginger pomace brandy with 0.40 g/L yeast addition got the highest total score.

Ranking results and significant difference from the cuppers were shown in Table 9. Through the sum of ranks, it could be concluded that ginger pomace brandy with 0.40 g/L yeast addition was the most popular.

Table 9 Quality ranking results of five different yeast addition of ginger brandy by 11 quality cuppers

Cuppers	Yeast addition(g/L)				
	0.25	0.30	0.35	0.40	0.45
1	3	4	2	1	5
2	4	3	2	1	5
3	5	4	1	2	3
4	5	4	1	2	3
5	4	3	2	1	5
6	5	4	1	2	3
7	5	4	3	1	2

	4	5	1	2	3
8	4	5	1	2	3
9	4	5	1	2	3
10	3	4	5	2	1
11	3	4	5	2	1
Sum of ranks	45	44	24	18	34
Significance	A	A	BC	CD	B

Table 10. Physicochemical properties of ginger brandy and its base wine with different fermentation temperature

		Fermentation temperature(℃)				
		16	18	20	22	24
Base wine	Alcohol content (%)	6.08±0.00e	6.24±0.00c	6.15±0.00d	6.33±0.01b	6.39±0.00a
	Fermentation time (d)	25d	20d	17d	17d	16d
	pH	3.14	3.10	3.09	3.08	3.07
	Reducing Sugar (g/L)	4.58±0.01a	3.61±0.01b	3.47±0.11c	3.16±0.01d	1.58±0.01e
	Total Sugar (g/L)	5.93±0.02a	3.70±0.02c	3.89±0.01b	3.33±0.02d	1.99±0.01e
	Total Acidity (g/L)	7.65±0.01e	7.79±0.00d	7.85±0.00c	8.01±0.00b	8.18±0.00a
	gingerol (mg/L)	45.36±0.03e	48.32±0.05c	47.14±0.03d	49.22±0.00b	50.12±0.05a
Brandy	Alcohol content (%)	29	29	29	29	29
	Total Acidity (g/L)	0.31±0.002e	0.32±0.007d	0.35±0.002c	0.36±0.002b	0.39±0.002a
	Total ester (g/L)	0.85±0.002e	0.98±0.002d	1.00±0.002c	1.07±0.002b	1.11±0.003a
	Volatile acids (g/L)	0.05±0.001d	0.09±0.010c	0.11±0.010b	0.14±0.010a	0.14±0.000a

3.5 Effects of fermentation temperature on the physicochemical properties and sensory evaluation of ginger brandy and its base wine

3.5.1 Effects of fermentation temperature on the physicochemical properties of ginger brandy and its base wine

Physicochemical properties of ginger pomace brandy and its base wine with different fermentation temperature were shown in Table 10. The alcohol contents of ginger pomace base wine were from 6.08% to 6.39%. Total acidity increased with the improved fermentation temperature. The base wine had highest total acidity at 8.18 g/L when the fermentation temperature was 24℃ while it had lowest total acidity at 7.65 g/L. When the fermentation temperature was 16℃. the lower the alcohol content was 6.08%, the higher the total sugar and reducing sugar were 5.93 g/L and 4.58 g/L, the lower the total acidity was 7.65 g/L. It might be due to that with the increasing temperature (16–24℃), the yeasts were closer to optimum fermentation temperature. Consequently, the yeast had stronger fermentation ability, and then consumed more sugar and produced more alcohol content. After alcohol contents of all samples were adjusted to 34%, the acidity of base wine correlates well with that of brandy (r=0.971, p＜0.01). The brandy had highest total acidity at 0.39 g/L when the fermentation temperature was 24℃ while it had lowest total acidity at 0.31 g/L when the fermentation temperature was 16℃. The brandy had highest total ester and volatile acids at 1.11 and 0.14 g/L, respectively, when the fermentation temperature was 24℃ while it had lowest total acidity and volatile acids at 0.31 and 0.05 g/L, respectively when the fermentation temperature was 16℃.

3.5.2 Principal component analysis of ginger pomace brandy with different fermentation temperatures by using electronic nose

Principal component analysis of ginger pomace brandy with different fermentation temperature by using electronic nose was presented in the Figure 9. The contribution rate of the first principal component (PC1) was 92.66%, while the contribution rate of the second principal component (PC2) was 5.1425%, and the total contribution rate of PC1 and PC2 was 97.803%, which was much higher than 85%. It was found that their PCA load diagrams were partial overlapped, indicating that these five ginger pomace brandies were similar in aroma.
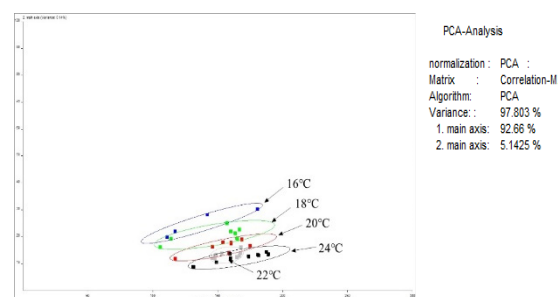

Figure 9. PCA load diagram of ginger pomace brandy with different fermentation temperature by using electronic nose

3.5.3 Sensory evaluation of ginger pomace brandy with different fermentation temperatures
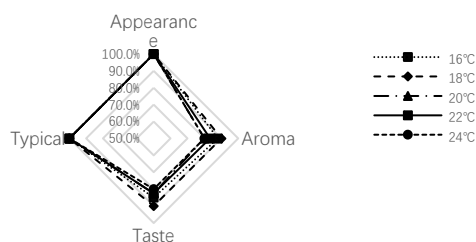

Figure 10. Radar chart of sensory score of ginger pomace brandy with different fermentation temperatures

Sensory evaluation of ginger pomace brandy with different fermentation temperatures was shown in Figure 10. All these samples had crystal clear appearance. Brandies with fermentation temperatures at 16℃ and 18℃ had the highest aroma score, which might be due to that the longer fermentation time led to extract more aroma from the ginger pomace. The brandy had highest taste score when the fermentation temperature was 16℃ while it had lowest taste score when the fermentation temperature was 24℃. All these five samples had the typical ginger flavor and scored 100% without great drawbacks. Brandy with the fermentation temperature at 18℃ had pleasant flavor, prominent ginger aroma, full body, proper gingerol strength and best typicity.

Ranking results from the cuppers was shown in Table 11. Through the sum of ranks, it could be concluded that ginger pomace brandy with fermentation temperature at 18℃ was the most popular.

Table 11 Quality ranking results of five different fermentation temperature of base wine of ginger brandy by 11 quality cuppers

Cuppers	Fermentation temperature(℃)				
	16	18	20	22	24
1	4	1	3	2	5
2	2	1	3	4	5
3	3	1	2	4	5
4	4	2	1	3	5
5	3	1	4	2	5
6	2	3	5	1	4
7	1	2	4	3	5
8	3	2	1	5	4
9	3	1	2	5	4
10	2	3	1	4	5
11	3	2	5	2	1
Sum of ranks	30	19	31	35	48
Significance	BC	CD	BC	B	A

4 CONCLUSIONS

The pH and total acidity of ginger brandy base wine were mainly influenced by ginger pomace/water ratio, yeast strain selection, sugar and yeast addition, fermentation temperature. While the gingerol content were mostly affected by ginger pomace/water ratio. The results of electronic nose analysis showed that main aroma components of ginger pomace brandy were mainly affected by ginger pomace/water ratio. In general, the optimized production technique was ginger pomace/water ratio at 1:3, 3# yeast strain, sugar and yeast addition (102 g/L and 0.40 g/L), fermentation temperature (18 ℃). Ginger brandy base wine made by above technique after second full distillation could produce ginger brandy with typical, strong and balanced ginger aroma, mellow and full-bodied taste, and long aftertaste.

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