Front. Agric. China 2011, 5(4): 529–533
DOI 10.1007/s11703-011-1128-9

RESEARCH ARTICLE

Quality evaluation of mixed brewed perries based on PCA and sensory evaluation

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Abstract **In order to improve the sensory quality of Yali perry and choose fruits specially suitable for mixed fermentation with Yali pear, 11 kinds of fruits were selected and contrasted, including hawthorn, kiwifruit, Kyoho grape, Brown plum, Fuji apple, Nanguo pear, Dongzao jujube, Mopan persimmon, Korla pear, and Chi pear. These fruits were mixed separately with Yali pear, thus turning out 64 different types of mixed perries. The assessment on products was made based on the physiochemical indexes, aroma components via gas chromatography-mass spectrometry (GC-MS), and comparison between the qualities of the mixed perries via sensory evaluation and principal component analysis (PCA). Based on the PCA on the physiochemical indexes of 39 mixed perries and aroma components of 7 mixed perries, the models aiming at evaluating perry flavor and aroma quality were established, which were compatible with those of sensory evaluation; based on the sensory evaluation and PCA, hawthorn, plum, grape, and apple were suitable specially for mixing brewing, among which the hawthorn-Yali perry in the proportion of 25:100 and plum-Yali perry in the proportion of 40:100 scored the highest. The results will be helpful to the development of perry industry.**

Keywords Yali pear, perry, sensory evaluation, GC-MS analysis, principal component analysis

Introduction

Perries are rich in nutrition, strong in aroma, and popular in each corner around the globe. In Hebei Province of China, the output of Yali pear (*Pyrus bretschneideri* Rehd cv. Yali) is immense, but the income of pear planters is relatively small. To multiply processing approaches, increase extra values, and thus get rid of the dilemma of pear production, it is advisable that a high-quality perry be produced. However, Yali pear alone can merely produce a light-flavored perry, which is poor in quality relevant to the lower contents of acid and polyphenol. Mixing brewing is always considered an important way to improve the quality of fruit wines, and the truth is that some wineries have indeed bettered off their wines and ciders this way (Ronald, 2008). Acidity has a deep impact on the quality of perry (Legin et al., 2003); therefore, pear juice can be altered in its acidity by sourer fruits, such as grape, tangerine, and apple, to brew better flavored perries (McGourty and Butzke, 1998). As for polyphenol, its significance is even definite (Li and Li, 1996; Villamor et al., 2009). Higher content of polyphenol tastes bitter and lowers the quality of fruit wine. Different types of polyphenol influence the astringent taste; for example, pigment with high degree of polymerization is highly correlated to the astringent taste but a little to the bitter taste (Josie et al., 2008). In addition, insufficient polyphenol content will lose the spirit of the fruit wine, resulting in frequent studies of pericarp impregnating condition for higher extracting efficiency of polyphenol (Nel, 2011). Aroma of juices may also influence the formation of fruit wine flavor (Patel and Shibamoto, 2003).

At present, only fewer studies on mixed aroma are available, and fruits mixed with pear are only apple, tangerine, and grape. Former researches were mainly focused on mixed perries derived from pear and one another fruit,

Received May 30, 2010; accepted June 27, 2011
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leaving a vacancy of study on various mixtures. Besides, gas chromatography-mass spectrometry (GC-MS) methods were never introduced to the analysis of perry aroma; therefore, the former achievements could only provide quite limited instructions to the perry production.

Materials and methods

Materials

Angel high activity dry yeast for wine (Q/YB.J02.5) was produced by Angel Yeast Co., Ltd. All 12 kinds of fruit, including Yali pear, hawthorn (*Prunus salicina* Bge.), kiwifruit (*Actinidia deleciosa* Planch.), Kyoho grape (*Vitis vinifera* L. cv. Kyoho), black plum (*Prunus salicina* Lindl.), Nanguo pear (*Pyrus ussriensis* Maxim. cv. Nanguo), Fuji apple (*Malus pumila* Mill.), Dong jujube (*Ziziphus jujube* Mill.), Mopan persimmon (*Diospyros kaki* L.), Xuehua pear (*Pyrus bretschneideri* Rehd. cv. Xuehua), Chi pear (*Pyrus bretschneideri* Rehd. cv. Tseli), and Korla Pear (*Pyrus bretschneideri* Rehd. cv. Korla), were purchased from market in October 2008 and then stored in the cold storage of Agricultural University of Hebei, China.

Fermenting method

Yali pear juice was extracted by adding sugar to the concentration of 18%,with the sugared pear juice as control (CK). 600 mL sugared pear juice was loaded into 1 L conical flasks, which was added respectively by other fruits with the core and pulp removed to obtain a total of 63 samples of hawthorn-Yali pear, black plum-Yali pear, Kyoho grape-Yali pear, Fuji apple-Yali pear, kiwifruit-Yali pear, and Nanguo pear-Yali pear at eight different proportions, namely, 5:100, 10:100, 15:100, 20:100, 25:100, 30:100, 35:100, and 40:100, and jujube-Yali pear, persimmon-Yali pear, Xuehua Pear-Yali pear, Korla pear-Yali pear, and Chi pear-Yali pear at the proportion of 20:100, 30:100, and 40:100. Samples with pH values higher than 3.7 ought to be adjusted to 3.5–3.7 by adding 1 M citric acid, while those with pH values lower than 3.7 remained unchanged, followed by adding 0.05 g/L potassium pyrosulfite, sealing, and sterilizing for 6 h. Activated Angel yeast with 5% sugar water at 40°C for 30 min was added into the juice at the rate of 0.3 ‰ according to dried yeast for fermentation at 23°C for 9 days, and the dregs were filtered out after the main fermentation. After post-fermentation for 20 days at room temperature and 3 months of time aging, the fruit wines were ready for physical and chemical testing and flavor ranking. Each experiment was performed three times.

Determination of experiment indexes

Determination of physiochemical indexes

Determination of alcohol level was conducted by GC method using 10 mL perry samples diluted by 2 to 10 times and added with 0.2 mL 4-methyl-2-pentanol as internal standard, increasing 80°C of column temperature to 180°C at the rate of 15°C/min. The injection port temperature and detection port temperature were 200°C and 220°C, respectively, with 60 MPa hydrogen, 0.75 MPa helium, and 0.5 MPa air.

Polyphenol determination was conducted by the Folin-Ciocalteus method (Li et al., 2008).

Sensory evaluation

The panels of seven tasters graded the wines by color, aroma, taste, and typicality at 20, 30, 40, and 10 grades, respectively. In the end, the four grades were summed up for each sample wine. Grading standards are listed in Table 1 (Niu et al., 2009).

Table 1 Grading standards for fruit wine sensory evaluation

Terms	Grading standard	Score	Rank
Color (20)	Clear, crystal, cheerful	18–20	A
	Clear, crystal, colored typically for fruit wine	15–17	B
	Clear, inclusion undetected, not so cheerfully colored	12–14	C
	Turbid, no luster, uncheerful	<12	D
Aroma (30)	Fruity, wine aroma strongly fragrant and coordinated	26–30	A
	Fruity, fragrant, and still coordinated	22–25	B
	Less fruity, probably with other smells, not appealing	18–21	C
	Undesirable smell, disgusting	<18	D
Taste (40)	Rich, strong, coordinated, and cheerful	36–40	A
	Coordinated, pure, and cheerful	30–35	B
	Either plain, bitter, sour, or astringent, unappealing	25–29	C
	Peculiar smell, disgusting	<24	D
Typicality (10)	Typical, unique, and excellent	9-10	A
	Typical and unique	8	B
	Typical, no so elegant	7	C
	Nothing typical	<6	D

Aroma extraction and assay

Metal HP-5 fiber (made by Supelco) was used in the headspace SPME mode to isolate aroma compounds from the wine samples (9 mL wine sample with the addition of 2 g NaCl in 15 mL headspace vial) for 40 min of incubation at 45°C. Analytes were thermally desorbed from the fiber into the GC-MS injector (Agilent 7890A/5975 C) for 2 min at 230°C. Agilent 7890A gas chromatograph was equipped with a 30 m × 0.25 mm (0.25 μm film thickness) HP-5MS fused silica capillary column and a flame ionization detector (FID). The GC oven temperature was started at 35°C for 5 min and then increased to 80°C at a rate of 3°C/min, and then to 100°C at a rate of 1°C/min, subsequently increased to 230°C at a rate of 10°C/min, and held for 3 min. The compounds of interest were identified by comparison of their spectra with the reference spectra according to the U.S. National Institute of Standards and Technology (NIST) (Pinheiro et al., 2002; Zhang et al., 2007; Radeka et al., 2008),

Statistical analysis

Data were statistically analyzed with the SPSS 16.0 software (P = 0.05) and shown in the form of means with standard deviations (mean±SD).

Results

Basic physiochemical indexes of the experimental fruits

Indexes of the experimental fruits are shown in Table 2. According to standard of a triple of the concentration of polyphenol and total acid in Yali pear, other fruits were categorized into four groups: fruits with high levels of both polyphenol and acidity, fruits with high level of acidity, fruits with high level of polyphenol, and fruits with only strong aroma.

Comprehensive sensory evaluation of mixed perries

Comprehensive sensory evaluation grades of mixed brewed perries are listed in Fig. 1. Contrasting with the pure Yali perry grade of 55.4, the best grades of mixed perries of 1–11 blends were 81.9, 46.4, 62.8, 75.3, 54.4, 68.6, 37.7, 47.9, 54.2, 56.6, and 57.2, respectively. The results showed that 1) hawthorn, grape, plum, and apple could improve perry quality greatly; 2) Chi pear and Korla pear had little influence on perry quality; and 3) kiwifruit, Nanguo pear, persimmon, jujube, and Xuehua pear deteriorated the perry quality, so the mixed perries brewed with these five kind fruits were excluded in the following analysis.

Table 2 Basic physical and chemical indexes of fruit

Fruit characteristics	Treatment group	Fruit	Acid content (g/100 g)	Polyphenol content (g/100 g)	Soluble solids content	Sugar content (g/100 g)
	CK	Yali pear	0.09±0.01	0.02±0.003	10.2	11.69±0.24
Both acid and polyphenol contents three times higher than those of CK	1	Hawthorn	3.27±0.08	0.77±0.06	20.8	16.4±0.76
	2	Kiwifruit	1.35±0.04	0.19±0.02	16.4	9.23±0.79
	3	Kyoho grape	0.49±0.03	0.11±0.004	15.6	16.2±2.75
	4	Brown plum	0.33±0.015	0.13±0.01	14.0	21.7±1.92
Acid content three times higher than that of CK	5	Nanguo pear	0.37±0.01	0.05±0.001	18.6	13.9±0.10
	6	Fuji apple	0.29±0.02	0.05±0.004	15.1	13.33±0.05
Polyphenol content three times higher than that of CK	7	Dong jujube	0.21±0.06	0.38±0.12	23.8	16.0±0.98
	8	Mopan persimmon	0.07±0.01	0.19±0.01	20.0	13.6±0.13
With strong aroma	9	Xuehua pear	0.05±0.01	0.03±0.01	14.0	13.05±0.13
	10	Chi pear	0.13±0.01	0.03±0.01	14.0	11.14±0.03
	11	Korla pear	0.08±0.01	0.02±0.01	19.3	11.04±0.51

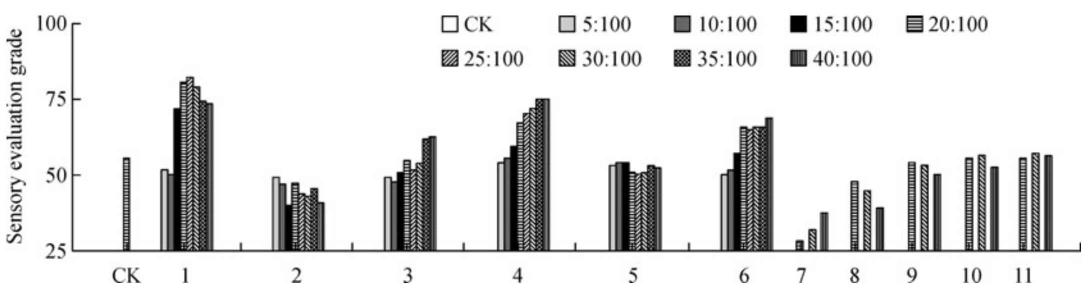

Figure 1 The comprehensive sensory evaluation grade of perries. Legend means the ratio of fruit to pear juice. CK is Yali perry. 1–11 are hawthorn-Yali perry, kiwifruit-Yali perry, grape-Yali perry, plum-Yali perry, Nanguo pear-Yali perry, apple-Yali perry, jujube-Yali perry, persimmon-Yali perry, Xuehua pear-Yali perry, Chi pear-Yali perry, and Korla pear-Yali perry, respectively.

Taste quality evaluation based on principal component analysis (PCA) model and sensory evaluation model

Construction of PCA model

After knock-outing the above-mentioned five categories of low-quality mixed perries, PCA was undertaken with the remaining six categories, i.e., the 39 kinds of mixed perries. In analyzing of the principle causes, $X_1, X_2, X_3, X_4, X_5, X_6, X_7$, and X_8 stood for alcohol level, pH value, solid content, total sugar, total acid, total amino acid, V_C, and polyphenol in the mixed perries, respectively. The PCA model for tasting quality is listed below:

$$F = 0.133X_1 - 0.098X_2 + 0.353X_3 + 0.324X_4 + 0.354X_5 + 0.203X_6 + 0.22X_7 + 0.37X_8$$

The mixed perries' tasting quality was compared based on F value, with a higher F value representing a higher tasting quality.

Taste quality comparison

Taste grades of mixed perries based on F value from PCA model and sensory evaluation model are listed in Fig. 2. The grades of hawthorn-Yali perries in proportions of 30:100–40:100 were above hawthorn-Yali perry of 25:100 from PCA model. The well-known exorbitant levels of acid and polyphenol could result in a rough taste in wines. Zhang discovered that high-quality grape wines had polyphenol contents of 1.62–1.82 g/L (Zhang et al., 2010), while Gu believed that normal grape wines had total acid below 7.09 g/L (Gu, 1996). Hawthorn-Yali perries with mixed proportions of 30:100–40:100 had a higher level of polyphenol (over 1.84 g/L) and total acid (over 8.84 g/L), and these qualities should be below 25:100 hawthorn-Yali parry (polyphenol 1.35 g/L and total acid 7.94 g/L). Eliminating these three hawthorn-Yali perries, the taste quality evaluation results based on PCA model and sensory evaluation model of the other mixed perries were roughly the same: 25:100 hawthorn-Yali perry, 40:100 grape-Yali perry, 40:100 plum-Yali perry, and 40:100 apple-Yali perry were best in their own groups.

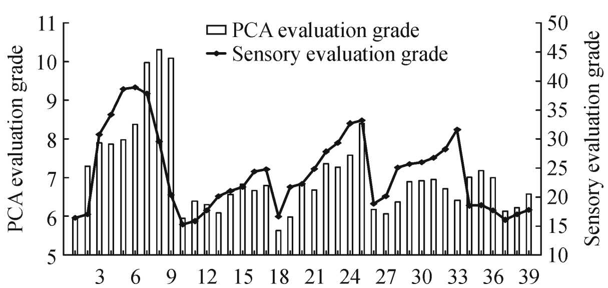

Figure 2 Tasting quality grade based on PCA model and sensory evaluation model. 1 is CK, Yali perry. 2–9 are hawthorn-Yali perry, 10–17 are grape-Yali perry, 18–25 are plum-Yali perry, 26–33 are apple-Yali perry, 34–36 are Chi pear-Yali perry, and 37–39 are Korla pear-Yali perry. In every group, the proportions increase in turn.

Aroma evaluation based on PCA model and sensory evaluation model

Aroma GC-MS analysis results of six kinds of mixed perries and Yali perry are listed in Table 3.

Construction of PCA model

X_1, X_2, X_3, and X_4 stood for the area ratios of alcohols, esters, acids, and other aroma, and further PCA analysis was undertaken. The PCA model of aroma quality was listed below:

$$F = -0.399X_1 + 0.431X_2 + 0.46X_3 - 0.05X_4$$

The mixed perries' aroma quality was compared based on F value, with a higher F value indicating a higher quality.

Aroma quality comparison

Aroma analysis results of GC-MS and sensory evaluation model are listed in Table 3. According to two evaluation models, the grades of 40:100 plum-Yali perry and 40:100 grape-Yali perry were not less than those of the Yali perry, and the grades of 15:100 hawthorn-Yali perry and 35:100 hawthorn-Yali perry were less than those of the Yali perry.

Conclusion and discussion

In recent years, PCA has been applied in most researches, and many models have been established (Heymann and Noble, 1989; Vidal et al., 2004; Yue et al., 2007). As a result, electronic noses have been built according to these models satisfactorily in wine quality comparison (Lozano et al., 2005; García et al., 2006). However, the previous models mainly aimed at gas molecules but not chemical indexes, and results showed more characteristics of olfactory evaluation and less of tasting evaluation.

In the former mixed perry reseaches, the purpose usually focused on finding the fittest ratio of fruit to pear; however, the work aiming at finding the appropriate species in perry brewing among different fruits has not been reported. In the present experiment, the authors figured out the fittest fruit species and best proportion among 11 common fruits in northern China by means of PCA method in olfactory and taste evaluation simultaneously.

Among these fruits, both hawthorn and plum are suitable for blew with Yali pear. As hawthorn and plum are of lower juice yield but with high acidity, hawthorn or plum alone is not suitable for producing fruit wine. Yali pear is juicy, and its blending with hawthorn or brown plum would have complementary advantages and thus produce high-quality fruit wines. Brownish red 25:100 hawthorn-Yali perry and ruddy 40:100 plum-Yali perry resemble dry red grape wine in

Table 3 Aroma analysis of GC-MS and sensory evaluation model

Perry types	Alcohols (%)	Esters (%)	Acids (%)	Others (%)	PCA grade	Sensory evaluation of perry aroma
40 : 100 plum-Yali perry	1.70	96.84	–	0.93	41.03	B
40 : 100 grape-Yali perry	2.34	97.03	0.31	–	41.04	B
40 : 100 apple-Yali perry	4.16	81.58	–	14.25	32.83	C
Yali pear	34.65	61.75	–	–	12.78	B
25 : 100 hawthorn-Yali perry	64.47	30.74	–	–	12.5	B
15 : 100 hawthorn-Yali perry	72.14	25.86	0.01	–	17.67	C
35 : 100 hawthorn-Yali perry	76.36	20.65	–	–	21.6	C

– means GC peak area less than 0.01% or component unidentified.

color, aroma, and flavor, so these mixed Yali perries ought to be competitive and of high market potential. Results of this experiment will have positive effect on enriching fruit wine types, improving Yali perry production in Hebei Province and increasing additional value to the industry of Yali pear.

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