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Oenological characteristics, amino acids and volatile profiles of Hongqu rice wines during pottery storage: Effects of high hydrostatic pressure processing

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ABSTRACT

Hongqu rice wines were subjected to high hydrostatic pressure (HHP) treatments of 200 MPa and 550 MPa at 25 °C for 30 min and effects on wine quality during pottery storage were examined. HHP treatment can significantly ($p < 0.05$) decrease the content of fusel-like alcohols and maintain the concentration of lactones in these wines. After 18 months of storage, the HHP-treated wines exhibited a more rapid decrease in total sugars (9.3–15.3%), lower free amino acid content (e.g. lysine content decreased by 45.0–84.5%), and higher ketone content (e.g. 6- and 14-fold increase for 2-nonanone). These changes could be attributed to the occurrence of Maillard and oxidation reactions. The wines treated at 550 MPa for 30 min developed about twice as rapidly during pottery storage than untreated wines based on principal component analysis. After only 6 months, treated wines had a volatile composition and an organoleptic quality similar to that of untreated wines stored in pottery for 18 months.

1. Introduction

Chinese rice wine, a popular traditional fermented alcoholic beverage, is one of the oldest alcoholic drinks in the world (Shen et al., 2012). Rice wine has been widely consumed in China for centuries because it is rich in amino acids and has a unique aroma, subtle flavor and low alcoholic content. It plays important roles in the daily life and culture of Chinese people. The three major groups of wine starters and raw materials are used in different types of Chinese rice wine: millet wine of northern China (including Jimo old wine of Shandong Province), wheat-qu rice wine (including Shaoxing rice wine of Zhejiang Province), and Hongqu rice wine (including Monascus purpureus rice wine of primarily Fujian Province; Lv et al., 2013). Hongqu has been used for many centuries to enhance the color and flavor of food including rice wine. Hongqu is made from the fermentation of steamed rice using the fungus *Monascus purpureus*. Journoud and Jones (2004) reported Hongqu contains a family of important secondary metabolites, such as monacolins and g-aminobutyric acid (GABA). These metabolites bring a bright red color, subtle sweet flavor, and health care functionality to Hongqu rice wine, making it likely to become a very popular rice wine internationally (Lv et al., 2013).

Traditionally, manufacturing Hongqu rice wine involved soaking and steaming rice, adding a starter culture, fermentation, pressing and storage (Shen et al., 2012). The astringent taste of young rice wines makes them seem flavorless and bitter after fermentation. Therefore, manufacturers commonly age these wines in sealed pottery to allow them to mature. Aging makes the wine body more uniform after experiencing many chemical and physical reactions during oxidative aging. Aging promotes chemical reactions between alcohol molecules, and between alcohol and water molecules. Aging accelerates the esterification of acids and alcohols, giving aged rice wine a more uniform and desirable fragrance, as well as a smooth taste (Shen et al., 2012). However, aging with traditional pottery has several drawbacks. Aging requires time and the cost of purchasing and storing pottery at the winery.

The wine industry has long used artificial means to accelerate the natural aging process. Scientists have studied the physical and chemical properties, flavors and constituents of wines using various chemical aging methods. Several emerging and novel physical technologies have some potential to replace traditional aging technology. Specifically, different wines have been aged with

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electric fields (EF), including pulsed (Wang, Su, Zhang, & Yang, 2015; Zhang et al., 2013) and alternating current (Zeng, Yu, Zhang, & Chen, 2008). Other techniques used to artificially age wine have produced inconclusive results including ultrasonic irradiation (Chang & Chen, 2002), gamma irradiation (Chang, 2003) and nanogold photocatalyzed treatment (Lin et al., 2008). All these methods reportedly shorten the aging time markedly, causing them to attract increased attention from scientists and winemakers. Nevertheless, scientists need to know how these physical treatments affect the quality of the wine.

Recently, aging wine with HHP has evolved as a relatively new technique. Generally, HHP may either inactivate undesirable microorganisms in wine or cause a change in its sensorial and physicochemical properties (Buzrul, 2012). Using HHP with low temperature reduces the initial population of bacteria, yeasts and molds in wine. Applying 500 MPa of pressure for 30 min or less has a significant antimicrobial effect on wine (Buzrul, 2012). Tabilo-Munizaga et al. (2014) found HHP (450 MPa for 3 and 5 min) caused structural changes to wine protein that improved their thermal stability and delayed haze formation in wine during storage. Santos, Nunes, Cappelle, et al. (2013), Santos, Nunes, Rocha, et al. (2013), Santos et al. (in press) and Santos et al. (2015) showed that HHP (400–600 MPa for few minutes (<10 min)) did not immediately alter wine physicochemical and sensorial properties, but influenced and/or accelerated wine aging during bottle storage. Tao et al. (2012) showed that extremely high pressure (650 MPa for 1–2 h) modified the physicochemical properties of red wine, lessened the color intensity and lowered the phenolic compound content. However, in the presence of French oak chips, the phenolic contents and antioxidant activity of the wine increased after HHP processing (Tao et al., 2016). Sun et al. (in press) found HHP treatment did not change the ability of experts to determine the grape variety and geographic origin based on phenolic acids and flavan-3-ols. These results could expedite the use of HHP processing in the wine industry. While many published studies have analyzed wines, little attention has been devoted to the quality of Chinese rice wine after HHP processing.

Therefore, the aim of this paper is to investigate the effects of HHP treatment on the changes in the physicochemical properties and quality of Hongqu rice wine, and its amino acid content and volatile profiles during pottery storage. It also compares treated wine with the evolution of those same quality characteristics in untreated Hongqu rice wine aged in pottery. This study elucidates whether HHP processing has the potential to accelerate the aging of Hongqu rice wine.

2. Materials and methods

2.1. Wine samples and high hydrostatic pressure treatments

Dry Hongqu rice wines obtained at the end of the alcoholic fermentation were obtained from Jishanghong (Fujian) Wine Co., Ltd., Fujian, China. Before HHP treatment, the wines were centrifuged at 3000 rpm, and filtered through 0.45 μm membrane (cellulose ester membrane, Millipore, Billerica, MA, USA). Wine samples was transferred aseptically into sterile polyethylene pouches and heat-sealed following the expulsion of air. The prepared pouches were placed into the HHP equipment (HPP-600MP, Kefa High Pressure Food Processing Inc., Baotou, Inner Mongolia Autonomous Region, China) with a 5 L cylindrical pressure chamber. HHP treatments at constant pressure of 200 MPa or 550 MPa for 30 min were conducted separately at 25 °C using water as the pressure medium (Xie, 2014). The average compression rate was approximately 1 MPa/s for 200 MPa and 2 MPa/s for 550 MPa treatments. The decompression time during both HHP treatments was nearly instantaneous. The pressure holding treatment time in this study did not include the pressure increase and decompression times. Because of the adiabatic heat, the temperature of water increased up to 26.7 ± 0.3 °C at 200 MPa and 29.2 ± 0.4 °C at 550 MPa at the beginning of pressure treatment and then decreased gradually to 25 °C. The untreated (control) and HHP-treated wines were sequentially stored for 18 months in pottery under the same temperature (10–15 °C) and relative humidity (60–70%).

All wine samples, the control ($0P_C$), 200 MPa ($0P_{200}$), and 550 MPa ($0P_{550}$) samples, were tested immediately after the initial treatment. Those same samples were tested again for both free amino acid and volatile compound content and for sensorial analysis at 6 months ($6P_C$, $6P_{200}$, $6P_{550}$, respectively) and 18 months ($18P_C$, $18P_{200}$, $18P_{550}$, respectively).

2.2. Physical–chemical properties of Hongqu rice wine

Six conventional physical–chemical parameters, including pH, alcohol (percentage of alcohol by volume), total sugars (TS), amino-acid nitrogen (AN), total acidity, and non-sugar solids, were determined trimonthly during 18 months storage, using official methods according to the Chinese National Standard GB 13662-2008.

2.3. Free amino acid analysis

Eighteen free amino acids of wine samples were analyzed using official methods according to the Chinese National Standard GB 4356-2012. The procedure was accomplished using a high performance liquid chromatography system (Agilent 1100, Agilent Technologies, Palo Alto, CA, USA) with a C18 column (Phenomenex, 4.6 mm × 250 mm, 5 μm), which was combined with a pre-column derivation. The column temperature was maintained at 40 °C. Free amino acids were separated by stepwise gradient elution using solvent A (crystallized sodium acetate:triethylamine: water = 1.64 g:0.5 μL:5 mL:1000 mL) and solvent B (acetonitrile: water = 8:2 (v:v)). The pH of solvents A was adjusted to 6.20 ± 0.05 using 20% acetic acid. The speed of flow was set at 1.0 mL/min and the detection wavelength was set at 254 nm.

2.4. Volatile compound analysis

For volatile compound analysis, 9 mL of wine samples were introduced into a vial containing 2 g NaCl with 15 mL headspace, and capped with a poly-tetrafluoroethylene/silicone septum (Supelco Inc., Bellefonte, PA, USA). A solid phase microextraction device (Supelco Inc.) containing a fused-silica fiber (75 μm length) coated with a 50/30 μm layer of divinylbenzene/carboxen/polydimethylsiloxane fiber was used. The vial was allowed to stand at 40 °C for 15 min to equilibrate its headspace. Then, solid phase microextraction fibers were exposed to the headspace while maintaining the sample at 40 °C for 30 min. Finally, the fibers were inserted into the injection port of the gas chromatograph for 5 min sample desorption. Gas chromatography–mass spectrophotometry analyses were performed on an Agilent 6890 gas chromatograph (Agilent Technologies, Palo Alto, CA, USA) coupled to a mass selective detector (HP 5973; Hewlett-Packard Co., Wilmington, DE, USA) operating in electron impact mode (ionization voltage, 70 eV). An HP-Innowax 19091N-133 capillary column (30 m length, 0.25 mm i.d., 1/4 lm thickness 0.25 μm) was used. The temperature program was 40 °C for 5 min, then programmed at 5 °C/min to 220 °C for 2 min. The injector, interface, and ion source temperatures were 250, 230, and 230 °C, respectively. Helium was used as the carrier gas at a flow rate of 1.1 mL/min. All compounds were identified by comparison to retention indices and the MS spectra with those in the mass spectral libraries (including Wiley