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Effects of low frequency ultrasonic treatment on the maturation of steeped greengage wine

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A B S T R A C T

To accelerate wine maturation, low frequency ultrasonic waves of 28 kHz and 45 kHz were used to treat the steeped greengage wine. The contents of total acid, total ester, fusel oils and the wine chromaticity were determined before and after the ultrasonic treatment. The volatile compounds were analysed by GC–MS method, and the sensory quality was evaluated by panelist. The results indicated that ultrasonic treatment of the steeped greengage wine at 45 kHz 360 W for 30 min was effective to accelerate the aging process, where the fusel oils and alcohol compounds were significantly reduced and acid and ester compounds were significantly increased.

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1. Introduction

Greengage wine is a popular alcoholic beverage in Southeast Asia, especially China, because of its characteristic fruit flavor and potential health benefits such as antioxidant and anti-cancer properties (Adachi et al., 2007; Chen, Wu, Liu, & Li, 2009; Jeong, Moon, Park, & Shin, 2006; Jo et al., 2006). The Chinese well-known story of "Discussing the heroes of the country while drinking greengage wine" happened more than 1800 years ago in Three Kingdoms Period has granted it a historical culture. Greengage wine can be made by two different processes: fermentation and steeping (Li & Zhou, 2005). Several researchers have demonstrated that greengage wine made by steeping greengage fruit in rice wine could be more effective in maintaining the fruit flavor than that of the fermentation method (Gao, Zeng, & Xiao, 2009; Yang, Wu, Wang, & Peng, 2005). The steeping process is also a common operation in most industry practice. After the steeping process, the wine forms the basic flavor and body, but it is widely recognised that freshly steeped wine is undrinkable due to the harsh taste, pungent smell and too high concentration of fusel oils. The fusel oils are one group of the main flavor components of greengage wine, but a high concentration of fusel oils may cause dizziness, headache, thirst, and other uncomfortable symptoms (Watson & Preedy, 2003;Hori, Fujii, Hatanaka, & Suwa, 2003). Therefore, it is essential for the freshly steeped wine to be aged until its sensory properties become pleasurable. Generally, fresh wine is aged by natural maturation which requires a long time (more than half a year) and huge space, and consequently, is a low efficiency method in wine industry (Tao et al., 2012). To solve this problem, scientists have worked out a number of chemical and physical accelerating aging methods, such as oak wood bucket storage, micro-oxygenation, ultrasonic wave, and ultra-high pressure treatments (Chang & Chen, 2002; Del Alamo, Nevares, Gallego, De Simon, & Cadahia, 2010; Madrera, Hevia, & Valles, 2013; Nevares & Del Alamo, 2008; Van Jaarsveld & Hattingh, 2012). However, there is little information on accelerating of steeped fruit wines including steeped greengage wine.

Ultrasonic wave, especially low frequency ultrasonic wave, can significantly accelerate some types of chemical reaction rates, and is reported to be a promising technique in shortening the wine aging process (Chang, 2005; Leonhardt & Morabito, 2007). Saterlay and Compton (2000) proposed that ultrasonic wave can create an acoustic cavitation of microbubbles. The violent implosion of these microbubbles leads to energy accumulations in hot spots, and generates extreme temperatures and pressures, which produce very high shear energy waves and turbulence (Hemwimol, Pavasant, & Shotipruk., 2006; Luque de Castro & Priego-Capote, 2007). Under this extreme micro-environment, chemical polymers are accelerated to be broken into numerous particles and recombined as new polymers with good flavor and body. In a recent critical review of ultrasonic wave on food

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properties and bioactivities, Soria and Villamiel (2010) concluded that the ultrasonic wave in a frequency range of 16–60 kHz is able to accelerate oxidation, polymerization and condensation of alcohol, aldehydes, esters and olefins in wines. A number of reports demonstrated that ultrasonic wave below 100 kHz could shorten the aging process of wine maturation (Chang, 2004; Chang, 2005; Leonhardt & Morabito, 2007). However, research on accelerating the aging of steeped greengage wine is still lack of information.

The objective of this study was to develop an accelerating aging method on steeped greengage wine by applying 28 kHz and 45 kHz ultrasonic treatment. The changes of flavor components as well as other substances in wine affecting the mouthfeel and quality, such as esters, acids and fusel oils, were evaluated after 15 days storage. This study may provide useful practical information to greengage wine industry in application of ultrasonic treatment in accelerating the wine aging.

2. Materials and methods

2.1. Materials

The fresh steeped greengage wine was kindly provided by Galore Food Co. Ltd, Zhongshan city, China. The fresh wine was made by steeping fresh greengage fruit in rice alcohols for one year. This is the conventional method of greengage wine manufacturing in Asia. Most of un-dissolved particles were removed from the wine by a series of filtering steps. The steeped greengage wine was filled in separate polyethylene terephthalate (PET) containers (2 L/each), and kept in a dark and dry environment (15 °C). After arrival of our laboratory, the fresh wine was stored less than 1 month before the experiment treatment. The alcohol concentration of the fresh wine was 17.5% (v/v). All solvents and chemicals (Sinopharm Ltd., China) used in this study were of analytical grade.

2.2. Ultrasonic treatment

The fresh greengage wine was treated by an ultrasonic KQ-600VDV bath (Ultrasonic Instrument, Kunshan, China) with two separate frequencies: 28 kHz and 45 kHz. The ultrasonic power was adjusted at 240, 300 and 360 W, respectively. The equipment was filled with water as a medium for ultrasonic vibration transmitting, and the water was replaced after each treatment to keep the same ultrasonic heating effect. About 300 mL of fresh steeped greengage wine was filled in a 500 mL erlenmeyer flask with lid to reduce evaporation of volatile components. Then, the flask was placed in the center of the ultrasonic bath to assure the consistent of ultrasonic treatment. Samples were collected after 10, 20, 30, 40, and 50 min of treatment and stored in sealed glass containers to prevent evaporation loss. Ultrasonic untreated fresh greengage wine was also prepared in the same way as control. The wines were analysed after 15 days of storage at a dark and dry environment (15 °C) when the major flavor components in the wines were relatively stable after the ultrasonic treatment.

2.3. Total acid and ester determination

According to China Food Industry Standards Collection (2000), the total acid of steeped greengage wine was measured by the neutralisation titration method and expressed as citric acid (g/L), and the total ester content was measured by the saponification reaction method and expressed as ethyl acetate (g/L).

2.4. Chromaticity determination

The chromaticity is one of the most typical sensory characteristics of fruit wines, which reflects the shade and intensity of the wine products (Rentzsch, Weber, Durner, Fischer, & Winterhalter, 2009). According to Glories (1984), the chromaticity (I) of fruit wine was the sum of absorbance at 420, 520, 620 nm ($I = A_{420} + A_{520} + A_{620}$). The chromaticity of wines were determined on an UV2600 spectrophotometer (Techcomp, Shanghai, China), using de-ionised water as reference.

2.5. Fusel alcohol determination

Fusel oils are by-products of wine-making industry, and are mainly composed of *n*-propanol, *n*-butanol, isobutyl alcohol and isoamyl alcohol (Lachenmeier, Haupt, & Schulz, 2008). In the present study, fusel oils refer to isobutyl alcohol and isoamyl alcohol because they are the main fusel oil components in Chinese traditional rice wine (Shen, 1998), which was used in the steeping of greengage fruit. Steeped greengage wine was distilled to eliminate the effect of wine colour and the distillation was used for the analysis. Total contents of fusel oils were determined by PDAB (p-Dimethylaminobenzaldehyde) colorimetry on the UV2600 spectrophotometer at 520 nm against reagent blank as reference (AOAC, 1984). The concentrations of individual fusel oils of isobutyl alcohol and isoamyl alcohol were determined by gas chromatography (GC 2010, Shimadzu, Japan) using a DB-WAX column (60.0 m × 250 μm I.D., 0.32 mm film thickness, Supelco, USA). Oven temperature program was: from holding at 40 °C for 5 min, to 180 °C with an increase of 10 °C/min, keeping for 5 min. The injection temperature was 250 °C. Flow rate were: N_2, 1.2 mL/min; H_2, 47 mL/min; air, 400 mL/min.

2.6. Volatile compounds determination

The volatile compounds of steeped greengage wine were extracted by headspace solid phase micro-extraction. The optimal ultrasonic-treated wine and untreated wine (8 mL each) were placed in 15 mL vials with 2.4 g NaCl respectively. The vials was sealed and preheated at 25 °C for 10 min. A CAR-PDMS extraction fibre (Supelco, USA) was inserted into the vials and fractionated from the sample matrix at 45 °C in a thermal block for 30 min until the equilibration of volatiles. Then, the fibre was removed and inserted immediately into an injection port of a gas chromatograph (GC 6890, Agilent, USA) and desorbed for 3 min at 250 °C.

The qualitative analyses of volatile compounds were carried out on a gas chromatography mass spectrophotometer (GC 6890/MS 5975, Agilent, USA) using a DB-WAX column (30.0 m × 250 μm I.D., 0.25 μm film thickness, Supelco, USA). Nitrogen was used as carrier gas with a flow rate of 1.2 mL/min. Oven temperature program was: from holding at 40 °C for 4 min, to 60 °C with an increase of 6 °C/min, then increasing by 10 °C/min until oven temperature reached 230 °C (8 min) and the injection temperature was 250 °C. The parameters of the mass spectrophotometer were: interface temperature, 250 °C; ion source temperature, 200 °C; electron impact (EI) spectra obtained at 70 eV; filament current, 200 μA; electrode stem source temperature, 350 °C; scanning mass range of 33–450 m/z.

The identification of flavor compounds was achieved by comparing the Kovats index (KI) of a series of *n*-alkane (C_7–C_{21}) with the mass spectra library of NIST98 (National Institute of Standards of Technology, Hewlett–Packard, MD, USA). The integration reports were accepted if matching degree was above 800. The relative contents of flavor compounds were determined by comparing the percentage of peak areas.

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