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The application of 20 kHz ultrasonic waves to accelerate the aging of different wines

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Abstract

Two different kinds of wine, one made from rice material and the other from maize material, were aged using 20 kHz ultrasonic waves (accelerated aging), which is widely used commercially. These two kinds of wine were also aged for 1 year in fired clay containers (standard aging, a standard conventional aging time in Asian market of rice wine). Comparisons of pH value, alcohol content, gas chromatography measurements, sensory evaluation and the time of aging were made between the two different aging processes on each of the wines. Results showed that the 20 kHz ultrasonic waves treatment aged rice wine much more quickly than standard aging, with similar quality, but did not age maize wine with comparable quality. The 20 kHz ultrasonic waves treatment has potential as a good alternative method of aging wine made from some materials but not all.

Keywords: Rice wine; Maize wine; Sensory; Ultrasonic waves; Aging

1. Introduction

Wine plays a relatively important role in life, socially and practically. Wine can be made from various materials using several processes. Wine making, however, needs time for fermenting and for aging. Fermenting produces the alcohol and aging improves the taste; and the combination makes wine pleasurable. Wine usually has several flavours and other properties which each play a subtle, intertwined, yet important, role in the tastes that humans prefer. Scientists have put much effort into studying the flavours, physical properties, chemical properties and constituents of wines made from various materials using different processes and aging techniques (Chen, 1998; Cocito, Gaetano, & Delfini, 1995; Huang, 1980; Jan, 1984; Masuda, Yamamoto, & Asakura 1985; Sato, 1984; Simpson & Miller 1983). There have been studies of wine aging using different chemical methods, but very little work dealing with accelerating wine aging by applying physical methods; thus, there is a lack of verifiable data in this field. Suslick (1989) reported that, in an ultrasonic waves process, high temperature and high pressure can be generated from circulated ultrasonic waves, causing chemical polymers to be broken into numerous mist particles (sub particles) and then recombined. Saterlay and Compton (2000) consolidated some information in "Sonoelectroanalysis—an overview," reporting exciting new advances in the area of sonoelectroanalysis and explaining the need for ultrasound power. They concluded that ultrasonic equipment, working in the range of 20–100 kHz, is relatively inexpensive, readily available and now proven to be an excellent enabling technology for electroanalysis. They further showed that the introduction of ultrasound into voltammetric cells has a marked effect upon their mass transport, which offers a dramatic improvement in reaction rates. Lindley and Mason (1987) also reported that the types of ultrasonic used for effecting chemical reactivity were broadly divided in power between 20 and 100 kHz. They pointed out that chemists are interested in ultrasound power because it provides a form of energy for the modification of chemical reactivity which is different from those normally used (i.e. heat, light, and pressure). Furthermore, Lindley and Mason (1987) also reported that ultrasound power produces its effects via cavitation bubbles. These bubbles are generated during the

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rarefaction cycle of the wave when the liquid structure is literally torn apart to form micro bubbles which collapse in the compression cycle. Lindley and Mason (1987) noted further that pressures of hundreds of atmospheres and temperatures of thousands of degrees are generated during the collapse of the bubbles. Cocito et al. (1995) studied the effects of rapid extraction of aroma compounds in must and wine by means of ultrasound by using 48 kHz ultrasonic waves. Matsuura, Hirotsune, Nunokawa, Satoh, and Honda (1994) studied the acceleration of cell growth and ester formation by ultrasonic waves irradiation. They investigated the possible application of 43 kHz ultrasonic waves to the fermentation control of wine, beer, and sake made from a saccharified rice solution, particularly in reducing dissolved carbon dioxide levels to give a better fermentation.

We hypothesized that the high temperature and high pressure generated from circulated ultrasonic waves might accelerate the aging process and give more flavour and/or taste to the wine. Thus, by applying this accelerated aging method, the aging would be achieved within a shortened time and space saved as well. A literature review was done, but very little work on wine aging, using a similar physical acceleration process, was found; so there is a lack of verifiable data in this field. Our paper reports the effects of using a band width of 20 kHz ultrasonic waves to age rice wine and maize wine. In particular, the effects on pH value, alcohol content, gas chromatography measurements, sensory evaluation and the time of aging were studied. The 20 kHz band width is in the range studied by Lindley and Mason (1987) and Saterlay and Compton (2000). It is relatively inexpensive, readily available and has been proven to provide the form of energy needed for the modification of chemical reactions. In this study, rice was chosen because it is relatively inexpensive, rich in starch (essential for alcohol fermentation techniques) and has less complex flavours and other properties compared to wines made from other materials for use in experimental analyzation. We also wanted to know whether the 20 kHz ultrasonic waves accelerated aging method is applicable to wines made from materials other than rice. Thus, a comparably priced material with similar grain properties, maize, was used as the other experimental variable. Both rice wine and maize wine were aged for 1 year in fired clay containers for comparisons. In this study, the aging year of the conventionally standard aging method was 1 year because 1 year maturation is the maturation time for the market product. We used maize wine as another variable in our study, so the maize wine was also matured conventionally for 1 year to match the condition of the conventionally matured rice wine. In Asia, most rice wine sold in the market is conventionally matured only for 1 year (or less) due to profit considerations, product quality, producers' costs and a selling price that consumers can accept. What we would like to learn from this study is whether the 20 kHz ultrasonic waves aging process has the potential to produce a wine comparable in quality to a conventionally aged wine.

2. Materials and methods

Both the rice wine and maize wine were made by cooking a 1:1 ratio of whole dry grain (14% water, dry basis) and water. After cooking and cooling to room temperature, *Aspergillus awamori* was inoculated into the rice and maize in order to break down the starch polymers into sugar monomers and liquefy the rice and maize for further fermentation. About 1 h later, *Saccharomyces sake* was then inoculated into the liquefied rice and maize and kept at 30 °C for fermentation. After the fermentations were completed, the rice wine and maize wine were collected by using the 80 °C distillation method.

The rice wine and maize wine that were aged by standard means were placed into separate fired clay containers for 1 year (the aging time in the Asian market for grain wine). The rice wine and maize wine aged by the accelerated process were subjected to a 20 kHz ultrasonic process as described in Fig. 1. A 20 kHz ultrasonic wave generator was used to apply ultrasound energy to the rice wine and maize wine. The ultrasonic wave generator had piezoelectric chips which generated electrons, when the electrons accumulated they vibrated to create ultrasonic waves. The energy of ultrasonic waves vibrated the wines and later forced the wines through a 10 mm orifice atomizer. The wine emerged in the form of a mist and the mist particles were then collected for further analyses. All the ultrasonic circulation treatments were in closed chambers to prevent evaporation loss of the wines and assure the best collection of the misted wines. Both the rice wine and the maize wine were treated repeatedly by this process up to 16 times. Samples of the treated rice wine and maize wine were collected after 0 (untreated), 4, 8, 12, and 16 treatments. Each sample was analyzed for pH value, alcohol

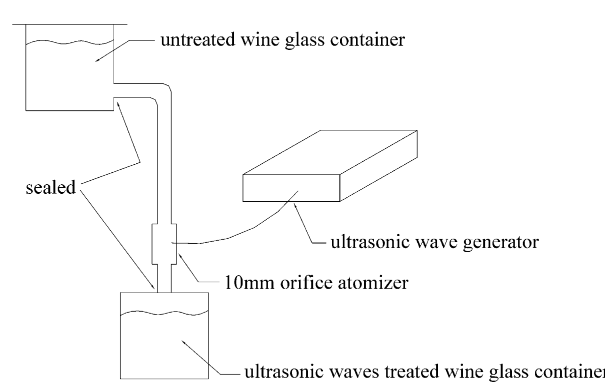

Fig. 1. Diagram of the ultrasonic waves set up.

content, gas chromatography measurements, sensory evaluation and time of aging. Moreover, each experimental treatment was replicated three times (e.g. three 1 year-aged wine samples obtained from three different containers) for analysis, and the results were the average of the three samples.

The pH value of all treatments of each sample was measured by a CORNING, pH meter 240. This gave an indication of acidity and the level of sour flavour of the rice wine and maize wine.

Alcohol was measured by a KYOTO, DA-310, electric specific gravity meter for each of the treatments. Alcohol was then calculated from the gravity measurements.

Flavour compounds were analyzed by a WHIRLPOOL 5790 gas chromatograph with a glass column that was 1.8 m long, 2 mm thick, packed with 6.6% carbowax and 20 M/80-120 mesh carbopack B Aw, using a flame ionisation detector (FID). The carrier gas was nitrogen with 20 ml/min flow rate. The injection temperature was 150 °C and the FID temperature was 200 °C. The temperature gradient started at 60 °C and stayed at that level for one minute. It then increased by 5 °C/min and reached 160 °C in 20 min where it stayed for 2 min. Each sample injection amount was 2 μl. Standards for the gas chromatograph were prepared as follows: 0.5 ml of 5.14% acetaldehyde, 0.4 ml of 5.01% methanol, 2 ml of 5.0% ethyl acetate, 0.2 ml of 5% 1-propanol, 0.4 ml of 5% 2-methyl-1-propanol, and 0.5 ml of 2% 2,3-dimethyl-butanol were each mixed with 40% ethanol to reach 100 ml of volume in total.

Sensory evaluations were made by 12 qualified and experienced wine sensory tasters using the Krammer method (Wang, 1980). Each of the 12 tasters tasted the rice wine and maize wine after 0 (untreated), 4, 8, 12 and 16 treatments of the 20 kHz ultrasonic wave process. The tasters ranked this rice wine against the conventional one year-aged rice wine. They gave it a ranking of 1 (best) to 5 (worst). The tasters ranked this maize wine against the conventional 1 year-aged maize wine. They gave it a ranking of 1 (best) to 6 (worst). Generally, a quality conventionally aged rice wine or maize wine would be ranked 1 on this scale. The results were then calculated and analyzed from the preference priorities of each taster and ranked from best to worst flavour.

Time of aging for the wines aged by the accelerated process was counted as the time needed to complete the whole ultrasonic wave aging process versus the 1 year conventional aging process.

3. Results and discussion

3.1. pH values

The pH value in 20 kHz ultrasonic waves treated rice wine increased slightly as the number of treatments increased, thus giving less sour taste (Table 1) and was preferred by the sensory evaluators (Table 3). The pH value in 20 kHz ultrasonic waves treated maize wine remained the same as the untreated maize wine as the number of treatments increased (Table 2).

3.2. Alcohol content

The alcohol content in the rice wine aged with 20 kHz ultrasonic waves decreased as treatment time increased, giving a less spicy flavour to the rice wine (Table 1). The alcohol content of the rice wine samples treated 16 times (52%) by 20 kHz ultrasonic waves was a little lower than the alcohol content of samples aged by the standard 1 year process (54%). The alcohol content in the maize wine aged with 20 kHz ultrasonic waves decreased slightly as the number of treatments increased (Table 2). The alcohol content of the maize wine samples treated 16 times (50%) by 20 kHz ultrasonic waves was about the same as the alcohol content of samples aged by the standard 1 year process (50%). The results showed that the alcohol lost in maize wine after the

Table 1
The pH value, alcohol content, acetaldehyde content and ethyl acetate content, of ultrasonic waves treated rice wine with different time treatments vs. one year conventionally aged rice wine and fresh rice wine (untreated)

Number of accelerated aging treatments	pH	Alcohol (%)	Acetaldehyde (mg/l)	Ethyl acetate (mg/l)	Polyols			
					Methanol (mg/l)	1-Propanol (mg/l)	2,3-Dimethyl-butanol (mg/l)	2-Methyl-1-propanol (mg/l)
0 (untreated)	4.9	56	105	103	58	160	1126	368
4	5.0	54	98	104	58	155	1088	361
8	5.0	53	89	105	57	150	1019	355
12	5.1	53	80	109	55	147	975	344
16	5.2	52	70	113	54	144	913	331
One year conventionally aged rice wine	4.8	54	90	115	54	154	933	355

ultrasonic process aging is slightly less than the alcohol lost in rice wine (Tables 1 and 2).

3.3. Gas chromatography

Acetaldehyde has the lowest boiling point of the flavour compounds, both in rice wine and maize wine, and has an unpleasant stingy flavour. Thus, by decreasing the amount of acetaldehyde in the 20 kHz ultrasonic waves-treated rice wine, other pleasant flavour compounds became more prominent, which made the 20 kHz ultrasonic waves treated rice wine taste better (Tables 1 and 3). But, because there was only slight decrease in the amount of acetaldehyde in the 20 kHz ultrasonic waves treated maize wine, both pleasant and unpleasant flavour compounds became more prominent which made this wine have a complicated taste that was less preferred by the sensory evaluators (Tables 2 and 4). Ethyl acetate, which is the fragrant compound in wine, was slightly increased in 20 kHz ultrasonic waves-treated rice wine but dramatically decreased in 20 kHz ultrasonic waves-treated maize wine (Tables 1 and 2). Alcohols, such as 1-propanol, 2-methyl-1-propanol, 2,3-dimethyl-butanol, and methanol, often have rice-oil flavours. When the levels of these decreased with the number of 20 kHz ultrasonic wave treatments, rice wine tasted smoother and less greasy in the mouth (Tables 1 and 3). When the levels of these alcohols increased with the number of 20 kHz ultrasonic waves treatments of maize wine, the stronger off flavour made the maize wine taste tart, spicy, and unsmooth. The acceptability decreased as the treatments increased (Tables 2 and 4).

3.4. Sensory evaluation

Wines usually have several flavours and other properties, each of them playing a subtle, intertwined, yet important role in terms of human preference. Some are not detectable in gas chromatography and thus human sensory evaluations are needed as references. Sensory evaluations showed that the taste of the 20 kHz ultrasonic waves treated rice wine improved as the number of

Table 2
The pH value, alcohol content, acetaldehyde content and ethyl acetate content, of ultrasonic waves treated maize wine with different time treatments vs. one year conventionally aged maize wine and fresh maize wine (untreated)

Number of accelerated aging treatments	pH	Alcohol (%)	Acetaldehyde (mg/l)	Ethyl acetate (mg/l)	Polyols			
					Methanol (mg/l)	1-Propanol (mg/l)	2,3-Dimethyl-butanol (mg/l)	2-Methyl-1-propanol (mg/l)
0 (untreated)	5.4	52	48	114	11	198	659	513
4	5.4	52	47	97	12	200	660	513
8	5.4	51	46	83	12	202	665	515
12	5.4	51	45	68	12	205	668	528
16	5.4	50	42	61	12	207	672	535
One year conventionally aged maize wine	5.4	50	40	121	11	200	658	513

Table 3
Sensory evaluation of ultrasonic waves-treated rice wine with different time treatments vs. one year aged rice wine and fresh rice wine (untreated)

Taster						
Rank	Untreated	4 ultrasonic wave treatments	8 ultrasonic wave treatments	12 ultrasonic wave treatments	16 ultrasonic wave treatments	One year aged rice wine
A	5	4	3	2	1	1
B	5	4	3	2	1	2
C	5	4	4	3	2	2
D	5	5	4	3	2	1
E	5	5	4	2	1	1
F	5	4	3	2	1	1
G	5	4	3	2	1	1
H	5	4	3	2	1	1
I	5	4	3	2	1	1
J	5	4	3	2	2	2
K	5	4	3	2	2	2
L	5	4	3	2	1	1
Rank summation	60	50	39	26	16	16
Preference	5	4	3	2	1	1

Table 4
Sensory evaluation of ultrasonic waves treated maize wine with different time treatments vs. one year aged maize wine and fresh maize wine (untreated)

Taster						
Rank	Untreated	4 ultrasonic wave treatments	8 ultrasonic wave treatments	12 ultrasonic wave treatments	16 ultrasonic wave treatments	One year aged maize wine
A	1	2	4	5	6	1
B	1	2	4	5	6	1
C	2	3	4	5	6	1
D	2	3	4	5	6	1
E	2	3	4	5	6	1
F	2	3	4	5	6	1
G	2	3	4	5	6	1
H	2	3	4	5	6	1
I	2	3	4	5	6	1
J	2	3	4	5	6	1
K	2	3	4	5	6	1
L	1	2	4	5	6	1
Rank summation	21	33	48	60	72	12
Preference	2	3	4	5	6	1

treatments increased (Table 3); while the taste of the 20 kHz ultrasonic waves-treated maize wine was rated progressively worse as the number of treatments increased (Table 4). The rice wine that was treated 16 times by 20 kHz ultrasonic waves had a taste equivalent to conventional 1 year aged wine (Table 3). Aging wine by ultrasonic wave treatment shows potential as an alternative method of aging rice wine, but not maize wine. Thus, the 20 kHz ultrasonic waves treatment has potential as a good alternative application method of aging some but not all kinds of wine. Further studies are needed to learn more about aging different wines from various materials and applying different ultrasonic wave powers.

3.5. Time of aging

The ultrasonic waves process of aging rice wine is much faster than the 1 year conventional aging process. Rice wine could potentially be aged to a quality taste of market rice wine within 1 week by using 20 kHz ultrasonic waves. Maize wine did not age properly with the ultrasonic waves process but took only about half of the time of rice wine to age this way. Wines made from different materials need different times to age using the ultrasonic waves accelerated aging process.

4. Conclusion

Ultrasonic wave treatment of rice wine was capable of aging wine to a similar quality of taste as the conventional method of aging (market aging way). The 20 kHz ultrasonic wave treatment is as a good alternative method for aging wine but not all kinds of wine. The ultrasonic wave process is a much faster aging process for wines (1 week or 3 days versus 1 year). However, further studies are needed to learn more about applying various ultrasonic wave energy methods to age wines made of various materials.

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