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The effects of gamma irradiation on rice wine maturation

Audrey Chingzu Chang*

I-Lan Institute of Technology, Number 6, Lane 75, Section 2, Lung Chuan Road, I-Lan City, 260, Taiwan

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Abstract

Rice wine was fermented with *Saccharomyces sake* and was matured using gamma irradiation (after fermentation) as an accelerated physical maturation method. Tests were conducted on the accelerated matured rice wine for appearance, titratable acidity, presence of gamma irradiation residues, alcohol content, gas chromatographic measurements and sensory evaluation. The relationship of the content levels of titratable acidity, alcohol, ester, volatile acids, and aldehyde to sensory evaluations was also studied, as well as the time of maturation. Results showed that the gamma irradiation, in a suitable dosage, appeared to be a suitable method for improving some rice wine defects and producing a higher taste quality in the rice wine, without the presence of irradiation residues. However, difficulties arose concerning public fears that gamma irradiation residues may remain in the rice wine.
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Keywords: Rice wine; Gamma irradiation; Maturation; Sensory evaluation

1. Introduction

The major components of wine are water and ethanol. Ethanol is also known as alcohol and alcohol can be used as a food, a drug or a fuel. Wine ethanol (alcohol) can have positive or negative effects on human health, behaviour, and mood. Wine ethanol (alcohol) is produced by alcoholic fermentation in which yeasts and other microorganisms convert glucose or other sugars to ethanol. Since glucose or other monosaccharides can be derived from many carbohydrates, wine making materials can come from very diverse plant sources, such as grains, fruits, beets and many other materials. Wine making, however, takes time for fermenting and for aging. Fermenting produces alcohol from the sugar, and produces flavour and taste from protein and/or other food components and/or their derivatives; however, it is aging which improves and perfects the wine properties that make wine pleasurable and increase its value (Alamo, Bernal, Nozal, & Gomez-Cordoves, 2000; Sato, 1984). Basically, as wine ages, there are changes that originate from the changes of alcohols, esters, volatile acids, and aldehydes in the wines, and research on wine aging, conventional and artificial, has been conducted. For example, Alamo et al. (2000) studied the variation of monosaccharides during wine aging, examining aspects such as oak wood origin and influence of the barrel manufacturer. Bambalov and Tzvetanov (1995) conducted a study of the effect of storage on some characteristics of yeasts used for sparkling wines. Besides these, many scientists have also studied the physical properties, chemical properties and constituents of wines made from various materials using different maturation and aging processes and techniques (Chang & Chen, 2002; Gonzalez & Luisa, 2001; Huang, 1980; Maduagwa, 1982; Masuda, Yamamoto, & Asakura 1985; Matsuura, Hirotsune, Nunokawa, Satoh, & Honda, 1994; Simpson & Miller, 1983).

With regard to the history of isotopes, in 1895 W.K. Roentgen discovered X-rays and in 1913 isotopes were found by F. Soddy. In 1933 I. Curie and F. Joliot found an artificial phosphorus isotope with radioactivity P-32. That was the first isotope produced in a laboratory rather than occurring naturally. After many milestones, reached by many scientists, the study of and applications of isotopes started to flourish and they began to be used widely in such areas as genetic engineering, medical and biochemistry applications, chemical engineering applications, and agriculture studies. Technically, the primary advantage of application of radiation from

* Corresponding author. Fax: +886-3-5724176.
E-mail address: czchang@ilantech.edu.tw (A.C. Chang).

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isotopes is low heat, or mass energy transmission; it is easy to control; no catalyst is needed; there are no contamination concerns and it is relatively inexpensive.

From a literature search, some applications of gamma irradiation in wine and/or wine-related fields were found such as application in wine making materials (Ayed, Yu, & Lacroix, 1999; Bachir, 1999), bottled beer sterilization (Rinke, 1968), effects of wine cork studies (Careri, Mazzoleni, Musci, & Molteni, 1999; West, 1990). However, the application of gamma irradiation, specifically, to wines that were internationally available, was relatively rare. Hua, Chen, Yu, and Huang (1989) studied the acceleration of yellow wine mellowness by using cobalt-60 gamma rays; it was written in Chinese and not published internationally. They conducted the study by using 10–60 krad gamma ray irradiation. Their results showed that the ester compounds were increased after gamma irradiation. When comparing yellow wine irradiated with 10–60 krad gamma rays to wine conventionally aged for half a year, a year, and one and a half years, they found that the irradiated yellow wine quality reached that of the one and a half year conventionally aged yellow wine. The flavour, taste and mellowness of the irradiated yellow wine improved. They also did a hygiene and safety experiment and showed that the irradiated wine had no influence on human health and that the hygienic quota satisfied their national standard. In their study, they performed toxicity tests on rats. Rats fed 10g/kg by weight were found to be safe. Also, an experiment on micro-nuclear cells showed negative results in rats; however, many important things were not described or not described in detail, plus the language was not English, nor was the publication available to the general public. Caldwell and Spayed (1989) studied the effects of gamma irradiation on chemical and sensory evaluation of Cabernet Sauvignon wine. In their study they found gamma irradiation of red wine did increase the chemical colour age of the Cabernet Sauvignon wines. Sensory evaluations found no perceivable difference between the doses (600, 1200, and 2400 Gy) used. Also the gamma irradiation did not decrease the astringency of the wines studied. They also reported that the use of higher dose rates to rapidly age Cabernet Sauvignon wines does not appear to be feasible. This paper did not have any information on the use of lower dose rates to rapidly age Cabernet Sauvignon wines.

In our research, rice material was chosen because rice wine is a popular product in the oriental market, and users include the Chinese, Japanese, and Koreans. Moreover, most scientists have already focussed on fruit wines, so a study of grain wines would contribute to the completeness of the field. The aim of this paper is to evaluate the effects of gamma irradiation treatment, at different irradiation doses, as a maturing technique for rice wine. We studied the effects of gamma irradiation on wine maturation in terms of appearance, titratable acidity, presence of gamma irradiation residues, alcohol content, gas chromatographic measurements, sensory evaluation, the relationship of the contents of titratable acidity, alcohol, ester, volatile acids, and aldehydes to sensory evaluations and the time of maturation.

2. Materials and methods

All the rice wine was made with a 1:1 ratio of whole dry grain rice (14% water content, dry basis, bought from the market) and water. The rice/water mixture was cooked at 125 °C for about 1 h and cooled to room temperature (25 °C). This process was done many times in our experiment in order to get a large enough quantity of cooked rice to produce the desired volume of rice wine for our experiments. *Rhizopus formosaensis* (ATCC 44167) was then inoculated into the rice in order to produce amyloglucosidase, glucoamylase, α-amylase, and β-glucuronidase to break down the starch polymers into smaller starch oligo carbohydrate polymers and sugar monomers and also to liquefy the rice for further yet more complete fermentation. About 1 h later, with the temperature constant at about 25 °C, *Saccharomyces sake* (CCRC 20262) was then inoculated into the liquefied rice and kept at 25 °C for fermentation. The fermentation took place in closed fired clay containers which were vibrated 2–3 times a day. After the fermentation was completed (14–16 days, depending on the alcohol content desired, e.g. 16–20% alcohol in our experiment), the rice wine was collected by using the 80 °C distillation method and was ready for the gamma irradiation treatments for accelerating the maturation process.

The rice wine was randomly grouped into five lots and bottled in 600-ml glass screw-cap wine bottles. For each lot, triplicate rice wine samples were irradiated at doses of 0, 200, 400, 600 and 800 Gy of cobalt irradiation at a dose rate of 20 Gy/min, using a cobalt-60 irradiator (plane source, 45.15 cm long, 1.11 cm diameter, Nordion, Canada) at the Institute of Nuclear Energy Research (Taiwan, R.O.C.). The rice wine was stored at room temperature around 25 °C for 7 days prior to analysis. Each sample was analysed for appearance, titratable acidity, presence of gamma irradiation residues, alcohol content, gas chromatographic measurements and sensory evaluation. The relationship of the contents of titratable acidity, alcohol, ester, volatile acids, and aldehydes to sensory evaluations, along with the time of maturation, was also studied. All analyses were done in triplicate and the results were the averages of the triplicate data.

The appearance of the rice wine colour was checked by the spectrometry method of AOAC (1995). The absorbance measurements were conducted at 520 nm using a

Beckmann DU-6 spectrophotometer with 1 mm path length crystal cuvette for all treated rice wine samples. This colour check was an index to see if there was a possible chemical interaction change of colour in rice wine through using the accelerating maturation method.

The titratable acidity was represented by using the total titratable acidity of acetic acid of rice wine due to its acid domination of the rice wine, and the titratable acidity value was measured by the AOAC (1995) method and converted by calculating the volume amount used of 1 N NaOH. This gave an indication of acidity and the level of sour flavour of the rice wine; it also was an index of possible contamination of the whole study and index of possible rancidity. The presence of gamma irradiation residues was tested for in all of the samples using the Geiger-Muller counter (Mini, EP15FL, UK) to check whether any possible contamination remained in the irradiated rice wine samples.

Alcohol was measured in all of the samples with a KYOTO, DA-310, electric specific gravity meter. Alcohol was then calculated from the gravity measurements. The alcohol content was an indication of possible alcohol loss in the process.

Flavour compounds were analysed 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 ionization 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 gas chromatograph temperature gradient starting at 60 °C and stayed at that level for 1 min. 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, 2 ml of 5.0% ethyl acetate, 0.2 ml of 5% 1-propanol, 0.4 ml of 5% *i*-butanol, 2-methyl-1-propanol, 0.5 ml of 2% 2-methyl-butanol, 1 ml of 3.04% 3-methyl-butanol, 0.4 ml of 5% ethyl lactate, and 2 ml of 2-phenyl-ethanol were each mixed with 40% ethanol to reach 100 ml in total.

Sensory evaluations were made by 12 qualified and experienced wine sensory tasters using the Krammer Method (Huang, 1984). Each of the 12 tasters tasted the rice wine before and after each of the gamma irradiation treatments. The tasters ranked the tasted rice wine with personal preference priorities by the overall opinions of the appearance, fragrance, smell, and the quality of the taste. They gave the tasted rice wine a ranking of 1 (best) to 5 (worst). Generally, the best quality rice wine of all the rice wine samples would be ranked 1 on this scale. The results were then calculated and analysed from the preference priorities of each taster and ranked from best to worst flavour.

The relationship of the contents of titratable acidity, alcohol, ester, volatile acids, and aldehyde to sensory evaluations was determined from the flavour compound results, analysed by instruments, and the results obtained by human taster evaluations.

Time of maturation for the wines matured by the accelerated process was counted as the time needed to complete the whole gamma irradiation maturation process.

3. Results and discussion

The results of the appearance of the rice wine colour check showed no change of colour for any tested samples in this study. That is, there was no appearance effect of gamma irradiation on rice wine maturation in our study.

Titratable acidity of all tested samples remained the same as the non-irradiated rice wine as the dosage of irradiation increased (Table 1). This showed that the acids, which also contribute to the flavour of wine, were not positively or negatively affected by gamma irradiation. It also showed that the study's fermentation process was correct; there was no rancidity and no contamination in the entire process.

The results of the contamination check for the presence of gamma irradiation residues in all gamma irradiation-treated samples showed that there was no contamination of these samples over the entire study. The results matched those found in literature reports and demonstrated that gamma irradiation could be a safe and applicable technique (Caldwell & Spayd, 1989; Eyck & Deseran, 2001).

Alcohol content did not show any change, so there were no effects on the alcohol content of rice wine by gamma irradiation (Table 1).

The following results were found in the gas chromatograph measurements. The amount of acetaldehyde, an off flavour, was slightly increased as gamma irradiation dosage increased (Fig. 1). Polyols, such as 1-propanol, *i*-butanol, 2-methyl-butanol, and 3-methyl-butanol (often considered to contribute to a bad, greasy mouth feel in wines) decreased as gamma irradiation dosage

Table 1
The titratable acidity value and alcohol content of gamma irradiated rice wine at different dosages

Gamma irradiation dosage (Gy)	Titratable acidity (g/100 ml)	Alcohol (v/v%)
0 (nonirradiated)	0.012	59
200	0.012	59
400	0.012	59
600	0.012	59
800	0.012	59

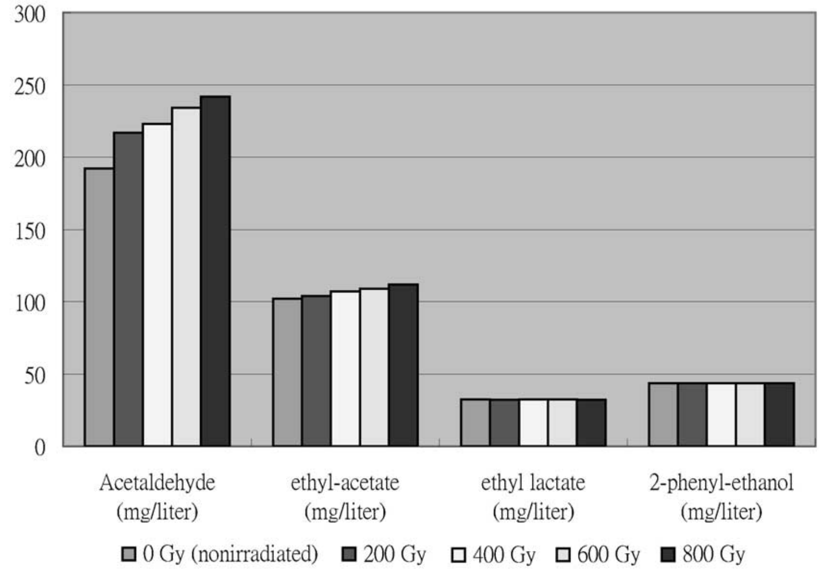

Fig. 1. The contents of acetaldehydes, ethyl acetate, ethyl lactate, and 2-phenyl ethanol versus gamma irradiation dosages.

increased (Fig. 2). The amount of ethyl acetate, which is considered to have a fruit fragrance, was increased as gamma irradiation dosage increased (Fig. 1). However, two other fragrant compounds of wine, ethyl lactate, which is also considered to have a fruit fragrance in wines, and 2-phenyl ethanol content, which is considered to have a rose fragrance, showed little change in amount after gamma irradiation (Fig. 2). These amounts fluctuated at the same level and results showed that the fluctuation range was less than 0.1 mg/l, which was considered to show no influence by gamma irradiation.

The results of sensory evaluations showed that the taste of the rice wine improved as the dosage of gamma irradiation increased (Table 2). This result showed that the gamma irradiation maturation technique on rice wine appeared to be a suitable method in achieving the maturation quality requirement to some extent. It improved some rice wine defects and produced higher taste quality in the wine at a suitable dosage.

The time of maturation, using gamma irradiation on rice wine, takes less than 1 h at our studied dose rate of 20 Gy/min. Rice wine could potentially be matured to a preferable taste quality in a much shorter time than the conventional maturation process. However, education on the elimination of radioactive residue fear needs to be emphasised.

The relationships of the contents of titratable acidity, alcohol, ester, volatile acids, and aldehyde to sensory evaluations were as follows: the titratable acidity and the alcohol content did not change throughout the entire study, and thus had no major effect on the process of the relationship of analytical measurements to sensorial evaluations. The esters and volatile acids can be considered in two parts. Ethyl acetate, which is

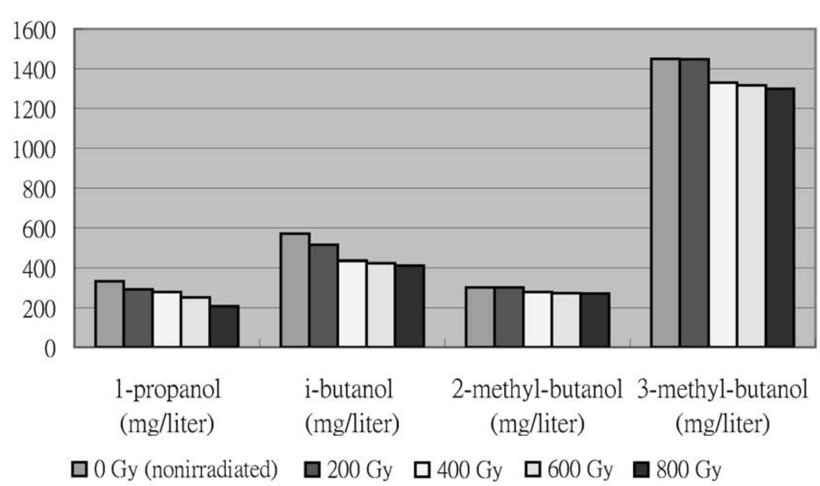

Fig. 2. The contents of polyols versus gamma irradiation dosages.

Table 2
The results of sensory evaluation of gamma irradiated rice wine

Rank	Taster				
	O Gy (nonirradiated)	200 Gy	400 Gy	600 Gy	800 Gy
A	4	3	3	2	1
B	4	3	3	2	1
C	4	4	2	1	1
D	5	4	3	3	1
E	5	4	3	2	1
F	4	4	3	2	1
G	5	4	3	2	1
H	5	3	3	2	1
I	4	4	2	2	1
J	4	4	4	3	1
K	5	4	4	3	1
L	5	4	3	2	1
Rank summation	54	45	36	26	12
Priority preference	5	4	3	2	1

considered as one good, fruit fragrance compound in wine, was slightly increased as gamma irradiation dosages increased. However, the other two fragrant compounds, ethyl lactate (fruit fragrance) and 2-phenyl ethanol (rose fragrance), remained unchanged. Consequently, they made no increased positive contribution to the taste of the matured rice wine. Yet, together with the increase of ethyl acetate and the decrease of polyols, the fragrance quality was still increased and results were found both analytically and sensorially (Table 2; Figs. 1 and 2). The polyols, which often have a greasy, rice-oil flavour and sometimes give the wine an aftertaste, were decreased. This, combined with the slight increase in ethyl acetate, to some extent, improved the mouth feel of the rice wine and the quality as gamma irradiation dosage increased (Fig. 2). However, the acetaldehyde, which is considered as unpleasant astringent in wine, also increased to some degree as gamma irradiation dosage increased. This might have subtracted some what from the improvement in taste due to the slight increase of ethyl acetate and decrease of polyols (Fig. 2).

In general, gamma irradiation appeared to be a suitable method for improving some defects and producing higher taste quality in rice wine. Time and space were saved as well. However, toxicity effects and the appropriate dosage check for different kinds of wine may need more study. The fear of contamination also needs to be reduced through public education.

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