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Fast aging technology of novel kiwifruit wine and dynamic changes of aroma components during storage

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Abstract

A novel kiwifruit wine (KW) fermented by *Aspergillus niger* and *Aspergillus oryzae* was developed with elegant flavor and poor alcoholic strength. The effects of natural aging, microwave and ultrasonic treatment on the quality of KW were investigated. A total of 61 aroma components were detected in the KW fermented by *Aspergillus niger* and *Aspergillus oryzae*. The results showed that microwave and ultrasonic treatments could promote the maturation of KW and increase the aroma components of KW. The variety of flavor components increased with a longer storage time. Combined with the taste evaluation analysis. The esters, alcohols, acids, and aldehydes in ultrasonic-aged wines were in dynamic balance and harmony with each other. The wine was soft and mellow, making the kiwi wine more typical.

Keywords: kiwifruit wine (KW); mixed fermentation; fast aging; ultrasonic aging; microwave aging.

Practical Application: The novel kiwi wine with suitable fast aging technology improved the quality of fruit wine, shorten the aging time, as well as saving costs, which would provide significant reference for the development of food industry.

1 Introduction

China is the leading producer of kiwifruit, ahead of all countries (Guo et al., 2017a), especially in the subtropical provinces of Taiwan, Guangdong, Guangxi Zhuang Autonomous Region, and Yunnan. Kiwifruit has many benefits for the human body, for the rich of vitamin C, organic acids, tannins, carbohydrates, pectin, essential amino acids, trace elements, inositol and lutein (Wei & Guohua, 2015; Satpal et al., 2021). Studies have shown that kiwifruit has many pharmacological properties, including antioxidant, hypoglycemic (Tyagi, 2015), constipation treatment (El Azab & Mostafa, 2022) and protecting the liver (Satpal et al., 2021), and so on. It is also shown that consuming kiwifruit after exercise in women can help relieve stress (Ali et al., 2021). With the development of cultivation and improved management techniques, kiwifruit production has increased significantly. Therefore deep processing techniques for kiwifruit have become increasingly important. Kiwifruit fruit wine, brewed from fresh kiwifruit pulp and juice is famous among many fruit wine products because of its unique flavor, richness in many nutrients and broad market prospect (Park et al., 2015). In addition to technological and chemical indicators, such as Brix, alcohol, acidity, and color, aroma characteristics are also essential factors in evaluating the quality of fruit wine (Rahman et al., 2022). The aroma components of fruit wine are not only related to brewing raw material (Englezos et al., 2016; Lu et al., 2021) but also related to brewing microorganisms, processing method, and fermenters (Akarca, 2020).

However, the aroma of kiwi fruit wine is still not satisfactory due to the traditional production technology. Single yeast fermentation often brought thin body taste and inconspicuous aroma, so mixed fermentation was gradually studied and used. Mixed fermentation has many advantages: shorter fermentation cycles, lower production costs, a wider variety of volatile aromatic substances, higher content of some aromatic components, richer layers of wine taste, and more stable quality of the finished product. The key factor for mixed fermentation was the ratio of strains. A strain of Kiwi wild mold was selected and mixed with yeast for the fermentation of kiwi wine (Sun et al., 2021). It was shown that the ethanol, color index, and organic acids of the wines were closely related to the inoculation method. Mixed fermentation produced a greater variety and concentration of volatiles than pure yeast fermentation.

The fermentation of fruit wines is a complex microbial reaction process. The final product contains a large number of volatile aroma substances in addition to alcohol and carbon dioxide. There are three primary sources of these aromatic substances: the various aromas produced during fermentation, the fruit itself, and the aromas resulting from complex chemical reactions during aging. The types and relative contents of different varieties' main aroma components in kiwifruit wines differed significantly. Different processing methods could also affect the aroma components of kiwifruit wine. The effect of skin maceration treatment on the aroma of kiwifruit wine was made from two representative kiwifruit varieties (kiwifruit "Asahi" and Chinese kiwifruit "Hort16A"). The results showed that the skin maceration treatment positively affected the aroma, leading to a significant increase in terpene content (Yiman et al., 2019). The effects of traditional systems (Limousin oak barrels and chestnut barrels) and alternative systems (stainless steel tanks with maceration plates and micro-oxidation) were compared after 12 months of wine aging. It was found that the innovative aging process and

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the chestnut wood accelerated the aging process, with better organoleptic quality of the wine and a more prosperous wood composition (Granja-Soares et al., 2020).

Daqu is one of the primary sources of microorganisms in liquor brewing (Wang et al., 2011). It contains many microorganisms that can secrete a variety of hydrolytic enzymes, and contributes to alcohol production and aroma presentation throughout the brewing process. *Aspergillus oryzae* and *Aspergillus niger* isolated from Daqu are commonly used in the production of Chinese liquor, with high saccharification power, while its acid tolerance and more acidic proteases secretion, can improve the rate of alcohol production (Liu & Sun, 2018), has been widely used in the brewing process. At present, the pectinase and other metabolites produced by *Aspergillus niger* are commonly used to produce various wines and juices, which can improve the juice yield and play a vital role in the clarification process. Previous studies have demonstrated that the joint function of high hydrolytic activities and a balanced collection of enzyme species secreted allow *Aspergillus oryzae* to function more efficiently in the utilization of raw materials, thus improving the quality of soybean paste fermentation (Hong et al., 2015; Kumazawa et al., 2013).

Due to the increased consumption of various fruit wines, the long process of traditional fermentation methods leads to high costs, occupying a large number of oak barrels, potential microbial contamination, and long fruit wine production cycles. In order to shorten the aging cycle of fruit wines, many studies were focused on innovative physical aging techniques, such as ultrasonic, microwave, and micro-oxygenation. It has been shown that some of the new physical aging techniques can make fruit wines more intense and increase their phenolic content. To explore the richer taste and flavor of kiwifruit wine, we mixed fermentation of *Aspergillus niger* and *Aspergillus oryzae* was used to make a novel harmonious kiwifruit wine. By comparing the effects of microwave and ultrasonic treatments on the flavor components of kiwifruit wine, a better method of rapid aging that does not affect the taste and flavor of kiwifruit wine would be found, thus can provide a positive reference for the development of the kiwifruit wine industry.

2 Materials and methods

2.1 Materials

Northeast high-quality japonica rice (commercially available); *Aspergillus niger* spore powder (Higuchi Matsunosuke Co., Ltd., Japan); black currant and rice currant (homemade in the laboratory); yeast strains: Association No. 9 (Japan Brewing Association); wild kiwifruit (Hubei Shennongjia Luyuan Natural Food Co., Ltd.); yeast nutrient (Tianjin Development Zone Wanbo Brewery Co., Ltd.).

2.2 Methods

Preparation of wine samples

Kiwi wine fermented by *Aspergillus niger* and *Aspergillus oryzae*: A 1:3 ratio of black currant and rice current and an artificial ferment of 15-40% kiwi pulp were added in a sealed jar and mixed well at room temperature according to the manufacturer's instructions. After fermenting for 9 days, the dregs were removed, and further fermentation was carried out at 18 °C for 18 days. The raw wine was obtained after removing dregs. All raw wines were filled with glass jars and aged for six months at room temperature. The fermented kiwi wine was divided into three groups: natural aging, microwave aging, and ultrasonic aging. After 0, 120, and 240 days of aging, the aroma components of the above nine groups were detected, and the method is shown below.

2.3 Wine samples pretreatment

Microwave treatment

300 ml kiwi wine was packed into 500 ml triangular jars, sealed with sealing film, and treated in a vacuum microwave apparatus (P70D20P-TD, Granz, China) at 700 W for 6 minutes, 3 times.

Ultrasound treatment

300 mL kiwi wine was packed into 500 mL triangular bottles and then immersed in an ultrasonic bath (DTC-10J, Dingtai Hensheng, China) of 40 °C for 20 min at 40 kHz ultrasonic frequency, under 40% ultrasonic amplitude, and 380 W ultrasonic power for a total of 2 times.

2.4 Space solid-phase microextraction and GC-MS conditions

Space solid-phase microextraction conditions

The extraction head (50/30 μmDV / CAR / PDMS) was aged for 1 hour at a gas chromatograph inlet of 250 °C. The accurately measured 10mL kiwifruit wine was loaded in a 15mL headspace bottle and sealed after adding 3g NaC1. After 40 minutes of extraction at 50 °C, the extraction unit was pulled out, and the bottle was inserted into the inlet of the gas chromatograph, allowing the kiwi wine to decompose at 250°C for 5 minutes. Moreover finally, the data was collected with the instrument.

GC-MS conditions

Gas chromatographic conditions: chromatographic column is DB-5MS, temperature programming: with an initial temperature of 50 °C, remain constant temperature for 5min, then heat to 250 °C at a rate of 5 °C/min, and hold for 1 min; inlet temperature is 250 °C, transmission line temperature is 280 °C, the carrier gas is high purity helium (99.999%); carrier gas flow rate is 1.0mL /min; no flow division. Mass spectrometry conditions: ion source temperature 230 °C; quadrupole temperature 150 °C; ionization mode EI; ionization voltage 70eV; scanning range 35 -500AMU.

Sensory evaluation

In order to evaluate the effects of different aging methods on the sensory quality of kiwi wine, a nine-point scale method was used by 20 trained members from a sensory evaluation team to evaluate each wine sample from the aspects of taste, acidity, taste, aroma, flavor, color and overall acceptability. Each sensory property is graded to indicate its intensity or preference.

The judges scored each attribute on a scale of 0-9, where 0 was the lowest intensity, and 9 was the highest. All evaluations were conducted in sensory booths at room temperature. The criteria of sensory evaluation are shown in Table 1.

3 Results and discussion

3.1 Influence of natural aging on kiwi wine quality

Fruit wines have a complex variety of aroma components in different flavors, making the styles of fruit wines more diverse and differentiated through synergistic and segregation effects. The aroma components of kiwifruit wine are complex, with esters, alcohols, acids, aldehydes, and ketones. Esters include ethyl acetate, ethyl lactate, and butyl formate; alcohols include methanol, isobutanol, isoamyl alcohol, n-propanol, and β-phenylmethyl (Han et al., 2021, Zhao et al., 2020).

From Figure 1, kiwifruit green wine includes 33 kinds of esters, 14 kinds of alcohols, 5 kinds of acids, 5 kinds of aldoketones and 9 kinds of other substances. The results are similar to those in other similar literature. After 120 days of natural aging, 65 main aroma components are detected, with 30 esters, 17 alcohols, 6 acids, 7 aldoketones and 5 other substances. After 240 days of natural aging, 71 kinds of aroma components are detected, with 33 esters, 19 alcohols, 7 acids, 8 aldoketones and 4 other substances. There are 54 aroma components detected in all three wines. For the main aroma components, in addition to ethyl alcohol, ethyl acetate, ethyl caprylate, isobutyl alcohol, isoamyl alcohol, acetic acid, capric acid, etc. are also in large amounts. These aroma components constitute the unique aroma characteristics of the naturally aged kiwifruit wine.

Trace aroma components are complementary. Although the content is shallow, these aroma components play a vital role in the overall quality of kiwifruit wine. It is the interaction between these substances that together shape the unique style of kiwifruit wine. The kiwi green wine has a pungent wine body and a bad mellow feeling. It should not be immediately consumed and need a certain period of storage. During this period, the kiwifruit green wine undergoes complex chemical reactions such as oxidation, reduction, esterification, condensation, and polymerization so that water molecules are reintegrated with alcohol molecules. The longer the storage time, the greater the correlation degree of the wine body. After that, the free degree of the alcohol molecules gradually becomes smaller. The pungency of the wine body weakens so that the wine is soft and tender, fruity aroma and wine body are mellow and natural, with dynamic balance achieved in aroma components.

From Table 2 and Figure 2, we can see that aroma components in kiwifruit wine undergo great changes after natural aging. There are 28 kinds of esters in kiwifruit green wine, mainly ethyl acetate, ethyl caprylate, ethyl phenylacetate, and ethyl decanoate. Varieties of esters increase with the extension of aging time, reaching 33 on 240 d. Butyl methacrylate, diisobutyl phthalate, and ethyl stearate are then newly formed, with relative ester amount rising from the initial 26.656% to 40.25% on 240 d. The contents of hexyl acetate, ethyl pelargonate and isoamyl acetate increase significantly, from 0.118% to 6.124%, 0.966% to 3.890% and 1.761% to 3.345%, respectively. There are 14 alcoholic substances, mainly isobutanol, isoamyl alcohol, and phenylethyl alcohol. By 240 d, alcoholic substance varieties increase to 19, with acetaldehyde diethyl acetal, 1-decanol, and lauryl alcohol formed. However, the relative content decreased from the initial 59.435% to 41.051%, possibly due to esterification and polymerization. Acid substance varieties increase from the initial 5 to 7 on 240 d, with newly formed 2-amino-4-methyl benzoic acid and octanoic acid. Its relative content increases from the initial 0.776% to 1.72%. The relative content of aldoketones substances firstly increases and

Table 1. The Criteria of Sensory Evaluation.

Sensory attributes		Score
Olfactory attributes	Fruity aroma	0-9
	Flowery aroma	0-9
	Sweet aroma	0-9
	Green and sour aroma	0-9
	Mellow aroma	0-9
Gustatory attributes	Bitterness	0-9
	Sour	0-9
	Astringency	0-9
	Sweetness	0-9
	Pungency	0-9
	Color	0-9
Appearance attributes	Clarification	0-9
Overall quality		0-108

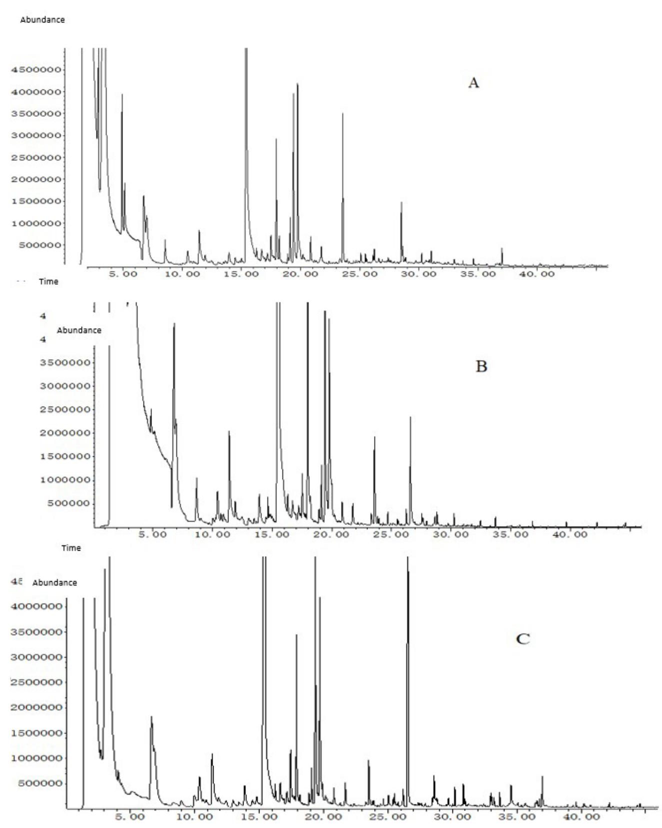

Figure 1. GC-MS total ion map of naturally aged kiwifruit wine at different storage time (A, B and C were GC-MS total ion diagrams of natural aging kiwi fruit wine with storage time of 0 d, 120 d and 240 d, respectively).

Table 2. GC-MS Analysis of Aroma Components of Naturally Aged Kiwifruit Wine.

Serial No.	Compound Name	Molecular Formula	Relative Content /%		
			0d	120d	240d
		Esters			
1	Ethyl formate	$C_3H_6O_2$	0.825	0.721	0.525
2	Ethyl acetate	C_4H_8O	4.024	3.675	3.467
3	Methyl butyrate	$C_5H_{10}O_2$	0.324	0.214	0.194
4	Ethyl butyrate	$C_6H_{12}O_2$	0.124	0.101	0.114
5	Butyl acetate	$C_6H_{12}O_2$	0.095	0.110	0.124
6	Isoamyl acetate	$C_7H_{14}O_2$	1.761	1.825	3.345
7	Ethyl hexanoate	$C_8H_{16}O_2$	1.181	2.298	4.412
8	Hexyl acetate	$C_8H_{16}O_2$	0.118	4.245	6.124
9	Butyl Methacrylate	$C_8H_{14}O_2$	0	0.017	0.035
10	Diethyl succinate	$C_8H_{14}O_4$	0.474	0.321	0.245
11	Ethyl caprylate	$C_{10}H_{20}O_2$	4.593	4.125	3.567
12	9-Decenoic acid ethyl ester	$C_{12}H_{22}O_2$	0.231	0.195	0.224
13	Benzyl acetate	$C_9H_{10}O_2$	0.003	0	0.001
14	Ethyl phenylacetate	$C_{10}H_{12}O_2$	3.81	3.569	4.577
15	Isoamyl hexanoate	$C_{11}H_{22}O_2$	0.007	0.024	0.031
16	Phenethyl acetate	$C_{10}H_{12}O_2$	2.893	2.568	2.721
17	Ethyl pelargonate	$C_{11}H_{22}O_2$	0.966	2.124	3.890
18	Methyl decanoate	$C_{11}H_{22}O_2$	0.059	0.042	0.065
19	Tert-Butyl perbenzoate	$C_{11}H_{14}O_3$	0	0	0.039
20	Ethyl caprate	$C_{12}H_{24}O_2$	3.829	4.215	3.949
21	Ethyl undecanoate	$C_{13}H_{26}O_2$	0.079	0.056	0.031
22	Ethyl laurate	$C_{14}H_{28}O_2$	0.681	1.242	1.856
23	Butyl Butyryllactate	$C_{11}H_{20}O_4$	0.198	0.112	0.091
24	Acetic acid 2-phenylethyl ester	$C_{10}H_{12}O_2$	0.018	0	0.009
25	Decanoic acid, 3-methylbutyl ester	$C_{15}H_{30}O_2$	0.028	0.017	0.012
26	Ethyl myristate	$C_{16}H_{32}O_2$	0.059	0.051	0.067
27	Octyl acetate	$C_{10}H_{20}O_2$	0.014	0.007	0.012
28	Diisobutyl phthalate	$C_{16}H_{22}O_4$	0	0.103	0.117
29	Ethyl (S)-2-hydroxypropionate	$C_5H_{10}O_3$	0	0.031	0.047
30	Ethyl Palmitate	$C_{18}H_{36}O_2$	0.223	0.273	0.323
31	Ethyl linoleate	$C_{20}H_{36}O_2$	0.014	0.007	0.004
32	Ethyl Oleate	$C_{20}H_{38}O_2$	0.025	0.021	0.015
33	Ethyl stearate	$C_{20}H_{40}O_2$	0	0.012	0.017
Total esters			26.656	32.321	40.25
		Alcohols			
34	Ethyl alcohol	C_2H_6O	29.918	27.187	23.126
35	Propyl alcohol	C_3H_8O	0.167	0.121	0.104
36	Isobutyl alcohol	$C_4H_{10}O$	3.123	2.894	2.534
37	Isoamyl alcohol	$C_5H_{12}O$	10.673	8.125	6.245
38	2,3-Butanediol	$C_4H_{10}O_2$	2.879	2.124	1.676
39	Acetaldehyde dimethyl acetal	$C_6H_{14}O_2$	0	0.021	0.034
40	Hexyl alcohol	$C_6H_{14}O$	2.352	2.589	2.012
41	N-caprylic alcohol	$C_8H_{18}O$	0.206	0.187	0.145
42	Phenethyl alcohol	$C_8H_{10}O$	9.14	6.25	4.23
43	2-Ethylhexyl alcohol	$C_8H_{18}O$	0.025	0.012	0.009
44	α-Terpineol	$C_{10}H_{20}O$	0	0	0.103
45	1-Nonanol	$C_9H_{20}O$	0.145	0.178	0.212
46	3-p-Menthanol	$C_{10}H_{20}O$	0.639	0.524	0.421
47	1-Decanol	$C_{10}H_{22}O$	0	0.008	0.014
48	Decyl alcohol	$C_{10}H_{22}O$	0.012	0.015	0.018
49	D-Citronellol	$C_{10}H_{20}O$	0.135	0.112	0.094
50	Lauryl alcohol	$C_{12}H_{26}O$	0	0	0.005
51	Diacetone-D-Mannitol	$C_{12}H_{22}O_6$	0.021	0.019	0.014
52	Cedrol	$C_{15}H_{26}O$	0	0.042	0.055
Total alcohols			59.435	50.408	41.051

Table 2. Continued...

Serial No.	Compound Name	Molecular Formula	Relative Content /%		
			0d	120d	240d
acids					
53	2-Amino-4-methylbenzoic acid	$C_8H_9NO_2$	0	0	0.462
54	DL-leucic acid	$C_6H_{12}O_3$	0.131	0.145	0.225
55	Acetic acid	$C_2H_4O_2$	0.345	0.415	0.382
56	Butyric acid	$C_4H_8O_2$	0.007	0.012	0.024
57	Capric acid	$C_{10}H_{20}O_2$	0.455	0.411	0.524
58	Octanoic acid	$C_8H_{16}O_2$	0	0.051	0.062
59	Lauric acid	$C_{12}H_{24}O_2$	0.021	0.032	0.041
Total acids			0.959	1.311	1.72
aldoketones					
60	Acetaldehyde	C_2H_4O	0.055	0.078	0.045
61	Benzaldehyde	C_7H_6O	0	0.017	0.012
62	Phenylacetaldehyde	C_8H_8O	0.031	0.043	0.027
63	Pelargonic aldehyde	$C_9H_{18}O$	0.062	0.076	0.061
64	Decyl aldehyde	$C_{10}H_{20}O$	0.498	0.576	0.356
65	3-Octanone	$C_8H_{16}O$	0	0	0.037
66	Damascenone	$C_{13}H_{18}O$	0	0.092	0.112
67	Geranyl acetone	$C_{13}H_{22}O$	0.136	0.241	0.175
Total aldoketones			0.776	1.111	0.819
others					
68	2-Chloro-2-nitropropane	$C_3H_6ClNO_2$	0.536	0	0
69	2,6-Dimethylmorpholine	$C_6H_{13}NO$	0.338	0	0
70	3-Isopropyl-6-methylene-1-cyclohexene	$C_{10}H_{16}$	0.272	0.243	0.198
71	Cycloheptatriene	C_7H_8	0.025	0.017	0.009
72	Vinyl benzene	C_8H_8	0.143	0.121	0.098
73	2,6-di-t-butyl-p-benzoquinone	$C_{14}H_{20}O_2$	0.105	0	0
74	2,4-Ditertiary butyl phenol	$C_{14}H_{22}O$	0.04	0.031	0
75	Heptadecane	$C_{17}H_{36}$	0.074	0.051	0.044
76	Oleylamine	$C_{18}H_{37}N$	0.007	0	0
Total others			1.54	0.463	0.349

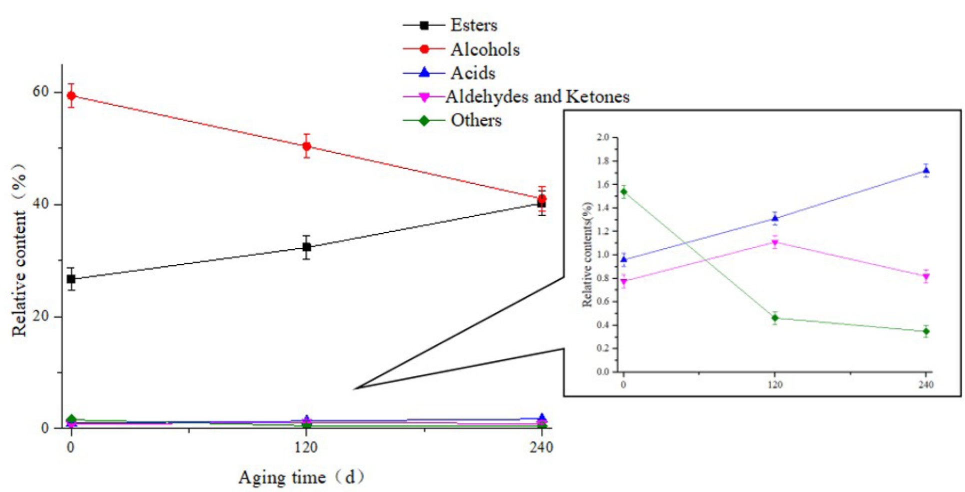

Figure 2. Change Law of Aroma Components in Naturally Aged Kiwifruit Wine.

then decreases. Its varieties increase from the original 5 to 8 on 240 d, with benzaldehyde and 3-octanone newly formed. In the meantime, varieties and contents of other substances in the wine body gradually decrease with the increase in aging days, with varieties decreasing from the original 9 to 4 and relative content decreasing from 1.54% to 0.349%. The above changes indicate that the wine body undergoes complex chemical changes during the aging process. These changes contribute to the typical aroma characteristics of kiwifruit wine mixed fermented by *Aspergillus niger* and *Aspergillus oryzae*.

26 compounds were identified and quantified in six commercial wines fermented by yeast strains, including seven higher alcohols, four acetates, nine acetates, four acids, and one ketone (Li et al., 2017). In this study, mixed fermentation of *Aspergillus niger* and *Aspergillus oryzae* could produce a large number of flavor components with different types of components, significantly higher than those reported in the study, indicating that mixed fermentation can reduce the homogeneity of aroma components of kiwi wines fermented by a single yeast strain.

3.2 Effect of microwave aging on the quality of kiwi fruit wine

Table 3, Figure 3 shows that 68 main aroma components are detected in the microwave-treated kiwifruit green wine, including 28 kinds of esters,18 kinds of alcohols, 8 kinds of acids, 8 kinds of also ketones, and 6 kinds of other substances. After 120d, 68 main aroma components are detected, with 28 esters, 19 alcohols, 9 acids, 8 ketones, and 4 other substances. After 240 days, 72 aroma components are detected, with 30 esters, 21 alcohols, 9 acids, 9 ketones, and 3 other substances. There are 54 aroma components detected in all three wines. Compared with kiwifruit wine aged for 240 days, ethyl 3-phenylpropionate, butyl benzoate, 2-methyl butanol, benzoic acid, furfural, octadecane, and 4-heptenal are newly formed.

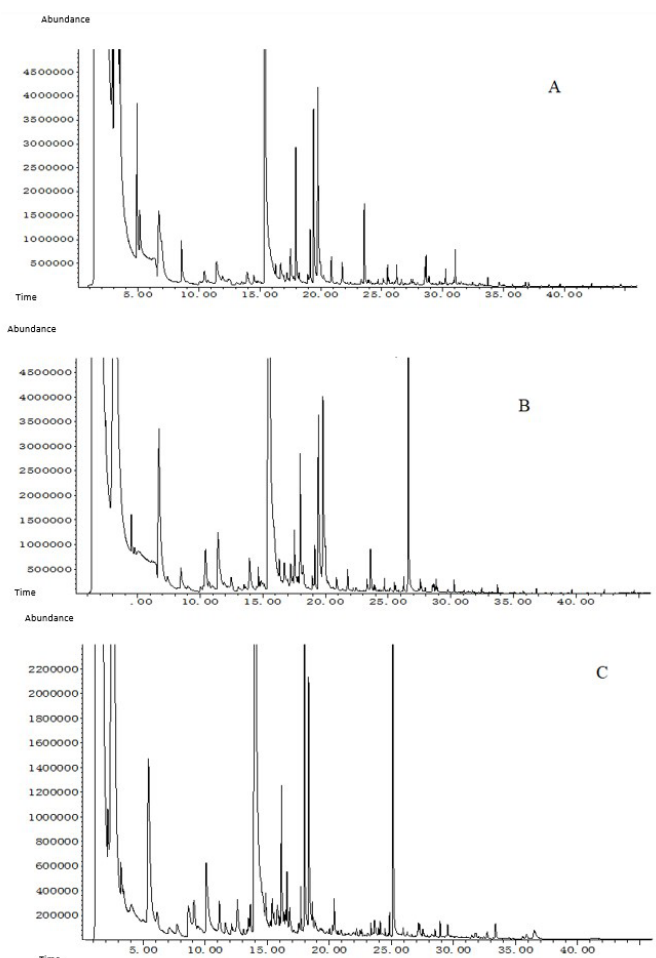

Figure 3. GC-MS total ion map of microwave treated kiwifruit wine at different storage time (A, B and C were GC-MS total ion diagrams of kiwi fruit wine aged by microwave with storage time of 0 d, 120 d and 240 d, respectively).

Microwave aging accelerates esterification and alcoholization of green wine using a microwave magnetic field. After the wine body absorbs microwave energy, the molecular energy is increased to accelerate chemical interactions between molecules in organic and inorganic systems so that alcohol esterification reaction is strengthened and content of the esters in the wine is increased, which gives ester flavor to the fruit wine and enhances aroma of fruit wine.

After microwave treatment, alcohols and total acids in kiwifruit green wine were decreased slightly, and the total esters were increased so that sensory score is improved. From Figure 4 and Figure 5, it can be seen that after microwave treatment, the alcohols in aroma components of kiwifruit green wine were slightly decreased. However, the varieties were increased from 14 to 18. The esters and ketones contents were increased, while the acids and other substances were decreased. After 240 d, compared with naturally-aged kiwifruit wine, varieties of esters substances in microwave treated kiwifruit wine were decreased from 33 to 30, but the relative content was increased from 40.25% to 41.76%. The microwave thermal effect accelerates the decomposition and oxidation of foreign flavor substances in the wine body. In terms of relative contents, other substances were decreased from 0.349% to 0.129%, acids substance increased, alcohols substance decreased slightly, with aldoketones remaining unchanged. The wine body is more coordinated and pleasant after the above series of complex physical and chemical changes. In summary, microwave treatment can promote kiwifruit wine's aging, rendering it pure, mild, and delicate in mouthfeel and highlighting its ester flavor.

Previous results showed that microwave had an effect on the physicochemical properties of young Cabernet Sauvignon dry red wines, and the change trend of chromaticity characteristics (CC) induced by microwave irradiation was consistent with the trend of red wine aging. Principal component analysis results showed that there were significant differences between untreated and treated red wines under different microwave conditions (Yuan et al., 2020). It suggests that microwave technology can promote the aging of red wines by changing some physicochemical properties, which is consistent with the results of this study.

3.3 Effect of ultrasonic aging on kiwi fruit wine quality

Table 4, Figure 6 shows that 68 main aroma components are detected in the ultrasonic treated kiwifruit green wine, including 29 kinds of esters, 18 kinds of alcohols, 7 kinds of acids, 8 kinds of aldoketones, and 6 kinds of other substances. After 120d, 68 main aroma components are detected, with 29 esters, 19 alcohols, 8 acids, 8 aldoketones, and 4 other substances. After 240 d, 72 kinds of aroma components are detected, with 31 esters, 21 alcohols, 8 acids, 9 aldoketones, and 3 other substances. There are 64 aroma components detected in all three wines. Compared with kiwifruit wine aged naturally 240d, methyl linoleate, methyl oleate, butyrolactone, p-methoxyphenylethanol, leaf alcohol, isobutyric acid, vanillic aldehyde, tert-butylhydroquinone, 4-tert-butyl-phenol are newly formed.

Table 3. GC-MS Analysis of Aroma Components of Microwave treated Kiwifruit Wine.

Serial No.	Compound Name	Molecular Formula	Relative Content /%		
			0d	120d	240d
		Esters			
1	ethyl formate	$C_3H_6O_2$	0.925	1.124	1.242
2	Ethyl acetate	C_4H_8O	3.464	3.875	4.123
3	methyl butyrate	$C_5H_{10}O_2$	1.324	1.414	1.474
4	Ethyl butyrate	$C_6H_{12}O_2$	0.156	0.101	0.148
5	Butyl acetate	$C_6H_{12}O_2$	0.074	0.123	0.156
6	Isoamyl acetate	$C_7H_{14}O_2$	1.874	2.525	3.445
7	ethyl hexanoate	$C_8H_{16}O_2$	0.997	1.898	4.521
8	Hexyl acetate	$C_8H_{16}O_2$	0.418	3.945	4.875
9	Dibutyl phthalate	$C_{16}H_{22}O_4$	0.104	0.242	0.312
10	Diethyl succinate	$C_8H_{14}O_4$	0.324	0.345	0.441
11	ethyl caprylate	$C_{10}H_{20}O_2$	4.124	3.615	2.876
12	9-Decenoic acid ethyl ester	$C_{12}H_{22}O_2$	0.331	0.165	0.232
13	Benzyl acetate	$C_9H_{10}O_2$	0	0	0.012
14	ethyl phenylacetate	$C_{10}H_{12}O_2$	3.21	3.869	4.617
15	Isoamyl hexanoate	$C_{11}H_{22}O_2$	0.018	0.021	0.033
16	phenethyl acetate	$C_{10}H_{12}O_2$	3.125	2.421	2.321
17	ethyl pelargonate	$C_{11}H_{22}O_2$	0.742	1.214	3.576
18	methyl decanoate	$C_{11}H_{22}O_2$	0.032	0.047	0.061
19	Ethyl 3-phenylpropionate	$C_{11}H_{14}O_2$	0.043	0	0.023
20	ethyl caprate	$C_{12}H_{24}O_2$	4.214	4.563	4.879
21	ethyl undecanoate	$C_{13}H_{26}O_2$	0.461	0.156	0.124
22	Ethyl laurate	$C_{14}H_{28}O_2$	0.571	1.332	1.495
23	Butyl butyryllactate	$C_{11}H_{20}O_4$	0.478	0.212	0.191
24	Decanoic acid, 3-methylbutyl ester	$C_{15}H_{30}O_2$	0.021	0.015	0.011
25	ethyl myristate	$C_{16}H_{32}O_2$	0.049	0.057	0.071
26	octyl acetate	$C_{10}H_{20}O_2$	0.034	0.023	0.018
27	butyl benzoate	$C_{11}H_{14}O_2$	0	0.024	0.047
28	Ethyl Palmitate	$C_{18}H_{36}O_2$	0.423	0.251	0.301
29	Ethyl linoleate	$C_{20}H_{36}O_2$	0.153	0.107	0.084
30	Ethyl Oleate	$C_{20}H_{38}O_2$	0.065	0.041	0.051
Total esters			27.754	33.725	41.76
		Alcohols			
31	ethyl alcohol	C_2H_6O	29.114	26.865	23.731
32	propyl alcohol	C_3H_8O	0.142	0.131	0.104
33	2-methylbutanol	$C_5H_{12}O$	0.231	0.202	0.182
34	heptanol	$C_7H_{16}O$	0.175	0.158	0.142
35	isobutyl alcohol	$C_4H_{10}O$	2.776	2.854	2.464
36	isoamyl alcohol	$C_5H_{12}O$	10.462	7.956	5.141
37	2,3-butanediol	$C_4H_{10}O_2$	2.782	2.084	1.616
38	Acetaldehyde dimethyl acetal	$C_6H_{14}O_2$	0.028	0.015	0.027
39	hexyl alcohol	$C_6H_{14}O$	2.212	2.449	1.912
40	n-caprylic alcohol	$C_8H_{18}O$	0.195	0.171	0.138
41	phenethyl alcohol	$C_8H_{10}O$	8.872	5.521	4.124
42	2-Ethylhexyl alcohol	$C_8H_{18}O$	0.019	0.011	0.006
43	α-terpineol	$C_{10}H_{20}O$	0	0	0.095
44	1-Nonanol	$C_9H_{20}O$	0.127	0.138	0.202
45	3-p-Menthanol	$C_{10}H_{20}O$	0.752	0.475	0.415
46	1-Decanol	$C_{10}H_{22}O$	0	0.009	0.017
47	decyl alcohol	$C_{10}H_{22}O$	0.021	0.015	0.018
48	D-Citronellol	$C_{10}H_{20}O$	0.125	0.108	0.084
49	lauryl alcohol	$C_{12}H_{26}O$	0	0	0.007
50	Diacetone-D-Mannitol	$C_{12}H_{22}O_6$	0.028	0.016	0.011
51	cedrol	$C_{15}H_{26}O$	0.012	0.048	0.065
Total alcohols			58.073	49.226	40.501

Table 3. Continued...

Serial No.	Compound Name	Molecular Formula	Relative Content /%		
			0d	120d	240d
		acids			
52	2-Amino-4-methylbenzoic acid	$C_8H_9NO_2$	0.004	0.345	0.474
53	DL-leucic acid	$C_6H_{12}O_3$	0.121	0.142	0.235
54	acetic acid	$C_2H_4O_2$	0.265	0.395	0.378
55	butyric acid	$C_4H_8O_2$	0.007	0.012	0.027
56	capric acid	$C_{10}H_{20}O_2$	0.181	0.423	0.531
57	Octanoic acid	$C_8H_{16}O_2$	0	0.048	0.068
58	lauric acid	$C_{12}H_{24}O_2$	0.018	0.037	0.048
59	Benzoic Acid	$C_7H_6O_2$	0.015	0.013	0.094
60	Isobutyric acid	$C_4H_8O_2$	0.011	0.007	0.002
	Total acids		0.622	1.422	1.857
		aldoketones			
61	acetaldehyde	C_2H_4O	0.055	0.084	0.051
62	benzaldehyde	C_7H_6O	0.003	0.015	0.011
63	Phenylacetaldehyde	C_8H_8O	0.025	0.039	0.024
64	pelargonic aldehyde	$C_9H_{18}O$	0.062	0.076	0.061
65	decyl aldehyde	$C_{10}H_{20}O$	0.498	0.574	0.351
66	furfural	$C_5H_4O_2$	0.031	0.024	0.014
67	3-octanone	$C_8H_{16}O$	0	0	0.033
68	Damascenone	$C_{13}H_{18}O$	0.004	0.087	0.142
69	Geranyl acetone	$C_{13}H_{22}O$	0.146	0.241	0.165
	Total aldoketones		0.824	1.14	0.852
		others			
70	2-chloro-2-nitropropane	$C_3H_6ClNO_2$	0.426	0	0
71	2,6-Dimethylmorpholine	$C_6H_{13}NO$	0.484	0	0
72	4-Heptenal	$C_7H_{12}O$	0.025	0.017	0.007
73	vinyl benzene	C_8H_8	0.173	0.131	0.081
74	4-tert-butylphenol	$C_{10}H_{14}O$	0.037	0.037	0
75	Octadecane	$C_{18}H_{38}$	0.067	0.042	0.032
	Total others		1.212	0.227	0.129

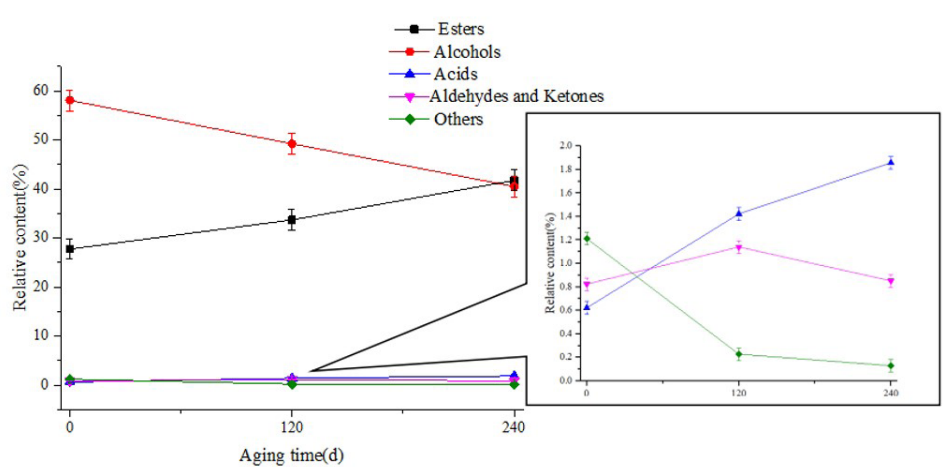

Figure 4. Change law of aroma components in microwave treated wine.

After ultrasonic treatment, the molecular activation energy of various substances in kiwifruit wine increases, generating a cavitation effect so that practical collision between molecules is enhanced, and esterification and redox reaction is accelerated, which contributes to the formation of the unique aroma of kiwifruit wine. At the same time, ultrasound waves can enhance the affinity of polar molecules in kiwifruit wine, and increase the degree of association between molecules, especially the degree of association between ethanol and water molecules, forming a stable polar molecule association group.

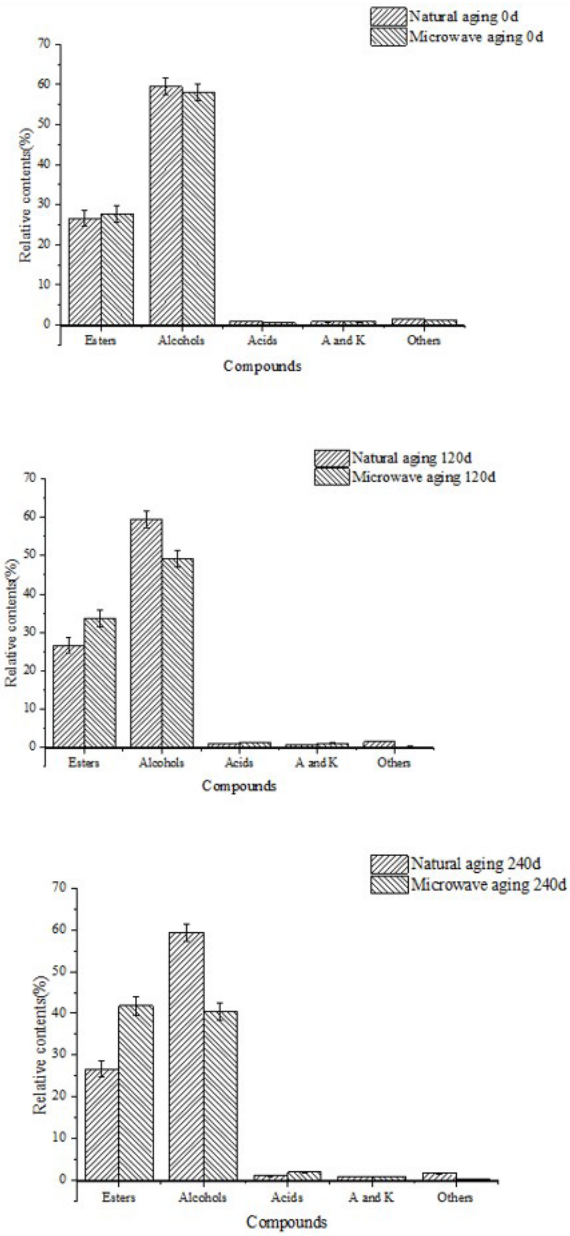

Figure 5. Changes in the relative content of various aroma compounds in microwave treated wine.

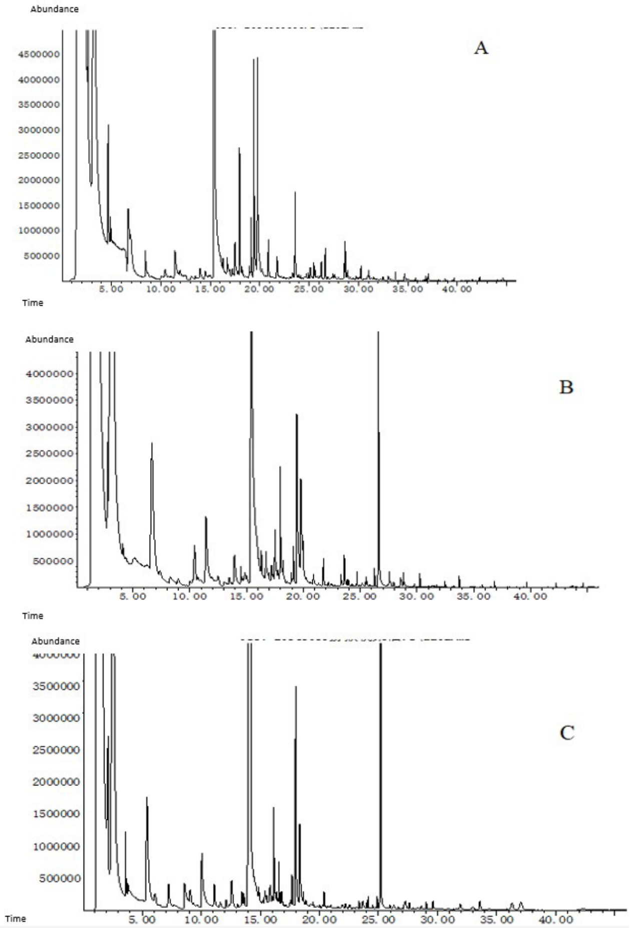

Figure 6. GC-MS total ion map of ultrasonic treated kiwifruit wine at different storage time (A. B and C were GC-MS total ion diagrams of kiwi fruit wine aged by ultrasonic wave for 0 d, 120 d and 240 d, respectively).

After ultrasonic treatment, the content of alcohol and total acid in kiwifruit green wine slightly decreases, and the content of total esters increases substantially. Therefore sensory score is improved. The result is consistent with previous results. From Figure 7 and Figure 8, it can be seen that after ultrasonic treatment, the content of aroma components in kiwifruit green wine changes significantly. Compared with naturally aged kiwifruit wine, the relative content of esters increases significantly from 26.656% to 31.93%, with varieties increasing from 28 to 29; the relative content of alcohols drops significantly from 59.435% to 52.919%, with varieties increased from 14 to 18; the relative contents of acids and also ketones slightly increase, while that of other substances decreases. These changes are in line with the variation trend in natural aging. After 240 d, varieties of esters in ultrasonically treated kiwifruit wine decrease from 33 to 31, but the relative content increases significantly from 40.25% to 41.76%. Varieties of alcohol substances decreased from 33 to 31, with relative content decreasing from 41.051% to 38.589%. The changes of esters and alcohols make fruit wine less astringent and render ester flavor coordinated with mellow. The cavitation neatly effect of ultrasound wave accelerates the arrangement of polar molecules in the wine body and polymerization and condensation reaction of low molecular compounds. The relative contents of acids and ketones slightly increase, while that of other substances decreases. After a series of complicated changes above, the whole fruit wine is more coordinated. In summary, ultrasonic treatment can promote kiwifruit wine aging, rendering it delicate in mouthfeel and highlighting its ester flavor.

The effectiveness of three new aging techniques, including additives combined with ultrasound, microwave or heat was evaluated by previous reports. The results showed that different aging techniques could affect the color and aroma components of grape pomace vinegar. The ester content increased significantly and the aroma components accumulated more under three aging techniques, especially the combination of additives with ultrasound. The total ester content of grape pomace vinegar treated with additives combined with ultrasound increased by 42.2% compared to natural aging at 16 °C for 180 days (Dong et al., 2020). It suggests that ultrasound can be a reliable technology for accelerating aging, which is consistent with this result.

Table 4. GC-MS Analysis of Aroma Components of Ultrasonic Treated Kiwifruit Wine.

Serial No.	Compound Name	Molecular Formula	Relative Content /%		
			0d	120d	240d
		Esters			
1	ethyl formate	$C_3H_6O_2$	1.123	1.134	1.271
2	Ethyl acetate	C_4H_8O	3.464	3.765	4.213
3	methyl butyrate	$C_5H_{10}O_2$	1.424	1.524	1.481
4	Ethyl butyrate	$C_6H_{12}O_2$	0.216	0.124	0.153
5	Butyl acetate	$C_6H_{12}O_2$	0.064	0.131	0.165
6	Isoamyl acetate	$C_7H_{14}O_2$	2.674	2.415	3.515
7	ethyl hexanoate	$C_8H_{16}O_2$	0.84	1.914	4.612
8	Hexyl acetate	$C_8H_{16}O_2$	0.478	4.021	4.765
9	methyl linoleate	$C_{19}H_{34}O_2$	0	0.242	0.312
10	Methyl oleate	$C_{19}H_{36}O_2$	0.894	0.724	1.243
11	Diethyl succinate	$C_8H_{14}O_4$	0.224	0.356	0.472
12	ethyl caprylate	$C_{10}H_{20}O_2$	4.224	3.513	2.766
13	9-Decenoic acid ethyl ester	$C_{12}H_{22}O_2$	0.431	0.265	0.212
14	Benzyl acetate	$C_9H_{10}O_2$	0.117	0	0.011
15	ethyl phenylacetate	$C_{10}H_{12}O_2$	3.331	3.924	4.711
16	Isoamyl hexanoate	$C_{11}H_{22}O_2$	0.027	0.018	0.042
17	phenethyl acetate	$C_{10}H_{12}O_2$	4.125	2.321	2.125
18	ethyl pelargonate	$C_{11}H_{22}O_2$	0.642	1.315	3.674
19	butyrolactone	$C_4H_6O_2$	0.042	0.043	0.071
20	Ethyl 3-phenylpropionate	$C_{11}H_{14}O_2$	0.071	0	0.032
21	ethyl caprate	$C_{12}H_{24}O_2$	5.314	4.163	4.874
22	ethyl undecanoate	$C_{13}H_{26}O_2$	0.561	0.156	0.124
23	Ethyl laurate	$C_{14}H_{28}O_2$	0.421	1.343	1.501
24	Butyl butyryllactate	$C_{11}H_{20}O_4$	0.376	0.244	0.195
25	Decanoic acid, 3-methylbutyl ester	$C_{15}H_{30}O_2$	0.033	0.017	0.013
26	ethyl myristate	$C_{16}H_{32}O_2$	0.039	0.061	0.073
27	octyl acetate	$C_{10}H_{20}O_2$	0.027	0.024	0.019
28	methyl palmitate	$C_{17}H_{34}O_2$	0	0.031	0.04
29	Ethyl Palmitate	$C_{18}H_{36}O_2$	0.513	0.551	0.403
30	Ethyl linoleate	$C_{20}H_{36}O_2$	0.163	0.101	0.091
31	Ethyl Oleate	$C_{20}H_{38}O_2$	0.072	0.04	0.061
Total esters			31.93	34.48	43.24
		Alcohols			
32	ethyl alcohol	C_2H_6O	27.114	25.865	23.731
33	propyl alcohol	C_3H_8O	0.138	0.121	0.094
34	p-Methoxyphenylethanol	$C_9H_{12}O_2$	0.224	0.189	0.171
35	Leaf alcohol	$C_6H_{12}O$	0.169	0.142	0.128
36	isobutyl alcohol	$C_4H_{10}O$	2.765	2.454	2.164
37	isoamyl alcohol	$C_5H_{12}O$	8.472	6.956	4.041
38	2,3-butanediol	$C_4H_{10}O_2$	2.672	2.012	1.516
39	Acetaldehyde dimethyl acetal	$C_6H_{14}O_2$	0.024	0.014	0.021
40	hexyl alcohol	$C_6H_{14}O$	2.201	2.439	1.812
41	n-caprylic alcohol	$C_8H_{18}O$	0.191	0.168	0.141
42	phenethyl alcohol	$C_8H_{10}O$	7.874	4.987	3.876
43	2-Ethylhexyl alcohol	$C_8H_{18}O$	0.018	0.01	0.005
44	α-terpineol	$C_{10}H_{20}O$	0	0	0.087
45	1-Nonanol	$C_9H_{20}O$	0.122	0.137	0.212
46	3-p-Menthanol	$C_{10}H_{20}O$	0.742	0.453	0.405
47	Decyl alcohol	$C_{10}H_{22}O$	0.028	0.014	0.017
48	D-Citronellol	$C_{10}H_{20}O$	0.123	0.108	0.078
49	lauryl alcohol	$C_{12}H_{26}O$	0	0	0.007
50	Diacetone-D-Mannitol	$C_{12}H_{22}O_6$	0.027	0.016	0.01
51	cedrol	$C_{15}H_{26}O$	0.015	0.048	0.058
Total alcohols			52.919	46.142	38.589

Table 4. Continued...

Serial No.	Compound Name	Molecular Formula	Relative Content /%		
			0d	120d	240d
		acids			
52	2-methyl propioric acid	$C_4H_8O_2$	0.212	0.345	0.491
53	DL-leucic acid	$C_6H_{12}O_3$	0.131	0.152	0.245
54	acetic acid	$C_2H_4O_2$	0.465	0.361	0.418
55	butyric acid	$C_4H_8O_2$	0.132	0.074	0.032
56	capric acid	$C_{10}H_{20}O_2$	0.192	0.472	0.571
57	Octanoic acid	$C_8H_{16}O_2$	0	0.052	0.071
58	lauric acid	$C_{12}H_{24}O_2$	0.023	0.041	0.052
59	Isobutyric acid	$C_4H_8O_2$	0.021	0.011	0.004
Total acids			1.176	1.508	1.884
		aldoketones			
60	acetaldehyde	C_2H_4O	0.061	0.082	0.057
61	benzaldehyde	C_7H_6O	0.011	0.017	0.015
62	vanillic aldehyde	$C_8H_8O_3$	0.031	0.043	0.027
63	pelargonic aldehyde	$C_9H_{18}O$	0.058	0.082	0.063
64	decyl aldehyde	$C_{10}H_{20}O$	0.631	0.561	0.348
65	furfural	$C_5H_4O_2$	0.041	0.031	0.017
66	acetoin	C_4H8O_2	0	0	0.034
67	Damascenone	$C_{13}H_{18}O$	0.007	0.076	0.145
68	Geranyl acetone	$C_{13}H_{22}O$	0.132	0.252	0.167
Total aldoketones			0.972	1.144	0.993
		others			
69	Eicosane	$C_{20}H_{42}$	0.418	0	0
70	tert-Butylhydroquinone	$C_{10}H_{14}O_2$	0.476	0	0
71	4-Heptenal	$C_7H_{12}O$	0.024	0.018	0.008
72	vinyl benzene	C_8H_8	0.168	0.126	0.079
73	4-tert-butylphenol	$C_{10}H_{14}O$	0.033	0.036	0
74	Hexadecane	$C_{16}H_{34}$	0.066	0.04	0.034
Total others			1.185	0.22	0.121

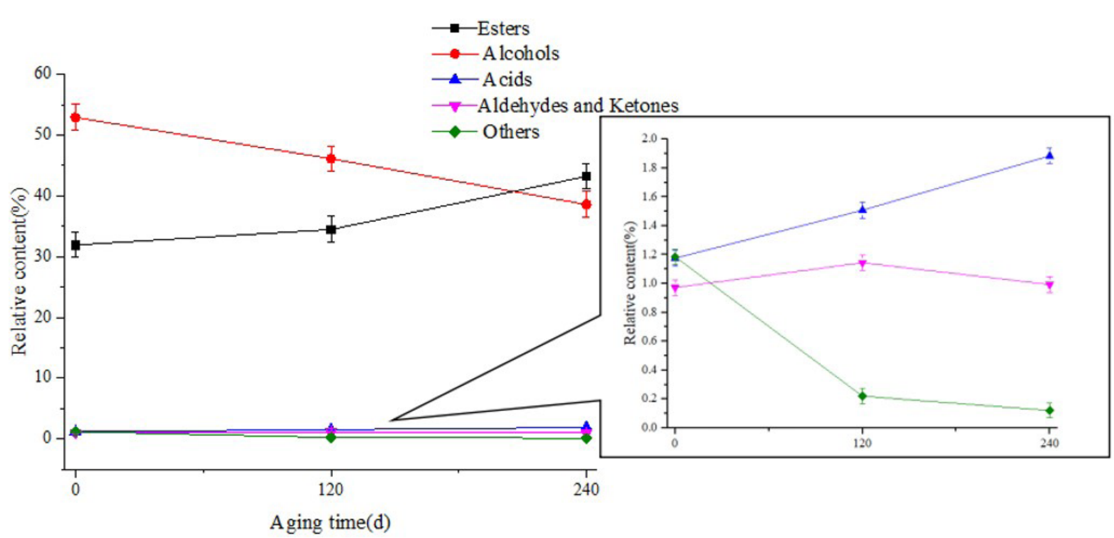

Figure 7. Change law of aroma components in ultrasonic treated wine.

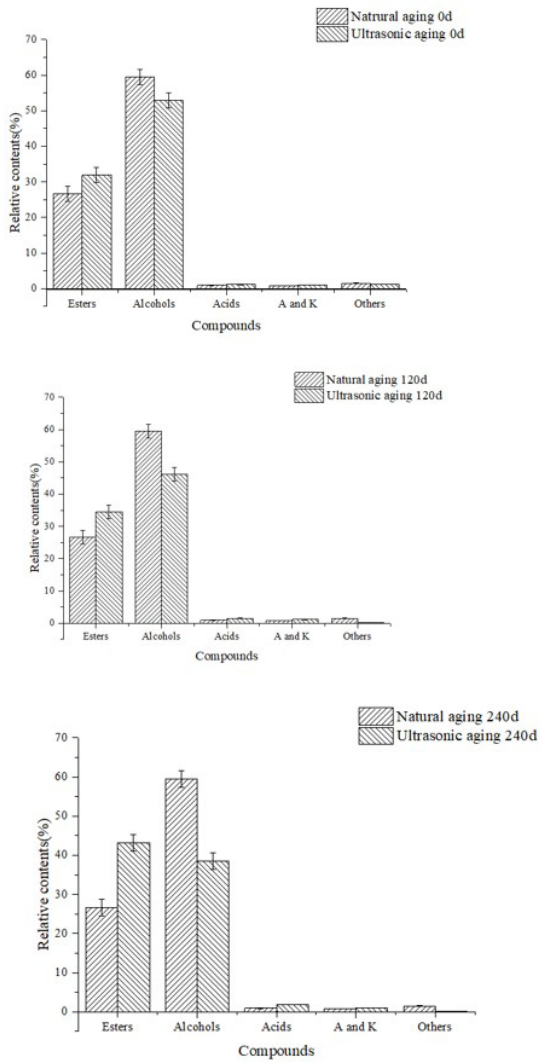

Figure 8. Changes in the relative content of various aroma compounds in ultrasonic treated wine.

3.4 Effects of different aging methods on sensory characteristics of kiwi wine

To profile the sensory characteristics of the 3 kiwifruit wines with different aging methods. The wines were evaluated by descriptive sensory analysis. The radar map of the mean sensory scores of the KW samples treated by 3 different aging methods is shown in Figure 9.

As shown in Figure 9, Samples treated by microwave and ultrasonic exhibited higher overall scores than natural samples. The olfactory attributes in ultrasonic aging seemed to have the highest levels, whereas the natural aging KW was the lowest. The gustatory score increased from natural aging to ultrasonic aging. However, the change of score representing fruit aroma and sour taste was contrary to the overall trend. This could be explained by the fact that microwave and ultrasound can accelerate the conversion of alcohols, acids, and esters with significant aroma characteristics, such as ethyl acetate, ethyl phenylacetate, and ethyl myristate. According to Table 4 and Figures 7-9, the promotion effect of the ultrasonic wave is more potent than that of the microwave. In a word, although the sour properties of natural aging KW are better than the other two wine samples, which have the effect of buffering and reconciling taste in the wines, the KW samples treated by ultrasonic are the best on the whole, which has smoother, mellower and richer feel in the mouth and a more harmonious flavor.

Compared with the other two treatments, the fruit aroma score of natural aging group was higher, which may be due to the higher content of hexyl acetate and ethyl caprylate, which had the aroma of raw pear and pineapple; while the sweet flavor of kiwi wine treated by ultrasonic was more significant, which may be due to the higher content of pelargonic aldehyde, ethyl linoleate and ethyl oleate. Moreover, ethyl oleate linoleate has cholesterol-lowering activity.

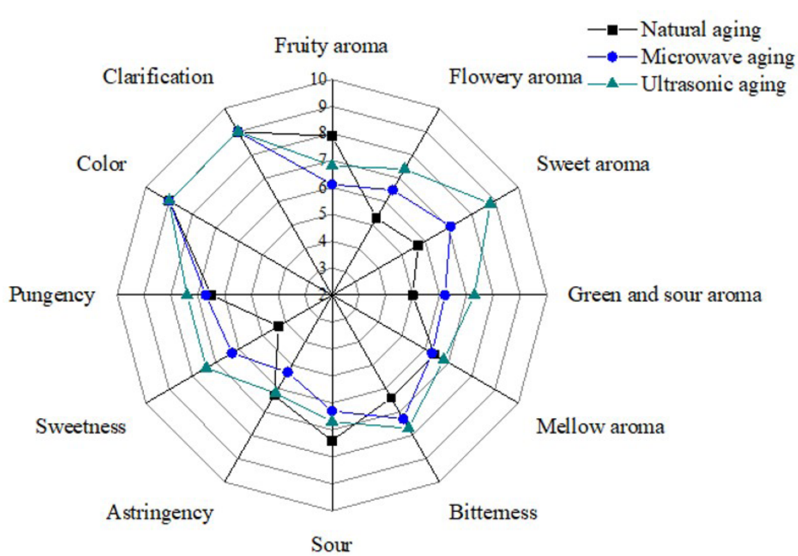

Figure 9. The radar map of the mean sensory scores of the KW samples treated by natural aging, microwave aging and ultrasonic aging.

4 Conclusion

This study investigates the effects of natural aging, microwave aging, and ultrasonic aging on the dynamic changes of aroma components of a novel kiwifruit wine. By comparing the dynamic changes of the relative contents and varieties of esters, alcohols, acids, and also ketones, the best aging method is determined for kiwifruit wine, and the following conclusions are obtained:

1. According to our results, the novel kiwifruit wine made from mixed fermentation of *Aspergillus niger* and *Aspergillus oryza* could bring better sensory characteristics and good quality. On the sensory scale, kiwi wine fermented by mixed fermentation had a unique presentation and typical bouquet, better than those fermented by Jiuqu and *Saccharomyces cerevisiae* EC1118 alone (Chen et al., 2019). In summary, mixed fermentation can improve kiwifruit wine quality and offer a broad application prospect for the production of kiwifruit wine.
2. There are 28 kinds of esters in kiwifruit green wine, mainly ethyl acetate and ethyl caprylate, which are the main factors affecting the fruit flavor of wine (Hu et al., 2018). With the extension in aging time, ester varieties increase, reaching 33 by 240 d, with butyl methacrylate, ethyl stearate newly formed, while ester relative content increases from 26.656% to 40.25%. Alcohol substance varieties increased from 14 to 19, mainly isobutanol, isoamyl alcohol, and phenylethyl alcohol, with relative content decreasing from 59.435% to 41.051%. It is probably the case that the relative lack of nutrients other than carbon source hindered the normal metabolism of yeast, resulting in the presence of isobutanol, isoamyl alcohol, and phenyl ethanol in kiwi wine (Carew et al., 2014), 1-decanol and lauryl alcohol form on 240 d. The wine body is translucent, and the astringency is significantly weakened.
3. After microwave treatment of kiwifruit wine, the alcohol content and total acid decreased , the percentage of total ester increased, the relative content of alcohol decreased, and the sensory score increased, which could be attributed to the microwave treatment that accelerated the rate of esterification, oxidation, and condensation in wine (Guo et al., 2017b). Under the microwave thermal effect, varieties of esters decreased from 33 to 30 on 240 d, and varieties of alcohol increased from 19 to 21. In contrast, relative contents of acids increased, and contents of aldoketones remained unchanged. This may be due to the natural volatilization of low boiling point acids and the hydrolysis of esters in liquor with the prolongation of aging time and the formation of corresponding acids and alcohols.
4. After ultrasonic wave treatment of kiwifruit wine, the alcohol content and total acid decreased, total ester content increased obviously, and relative content of alcohols decreased significantly. It could be accounted that the ultrasonic wave can promote the reassociation of molecules, the oxidation of alcohols into acids, and the corresponding acids react with alcohols to form esters. Therefore, the relative contents of esters such as ethyl caproate and ethyl lactate increase (Zheng et al., 2014). Under the cavitation effect of ultrasonic waves, varieties of ester substances dropped from 33 to 31 on 240d, varieties of alcohols increased from 19 to 21, relative contents of acids and ketones increased slightly, and relative content of other substances decreased. After ultrasonic treatment, kiwifruit wine has a more delicate mouthfeel and a more prominent ester flavor.
5. Both microwave and ultrasound waves can promote the maturation of kiwifruit wine mixed fermented by *Aspergillus niger* and *Aspergillus oryzae*, and the oxidation and esterification reactions in kiwifruit wine could be accelerated, allowing the percentage of ester substance to increase in wine body and alcohols and other substances to decrease. In this way, dynamic balance and mutual coordination are achieved in esters, alcohols, acids, and ketones. The wine body is tender and pleins, bringing a more prominent typicality of kiwifruit wine. Regarding the better method, the ultrasonic aging method's sensory quality and comprehensive index were better than the other two methods. It is probably the case that ultrasonic can remove the oxygen in the wine, which will affect the oxidation, condensation, and polymerization of phenols and acids (Lukić et al., 2019), but the presence of oxygen will also accelerate the aging process of wine. Therefore, performing the research on the control of oxygen content in the winemaking or maturation process is of great significance to the development of future wine industry research.

Nowadays, people's pursuit of new-type healthy food is more and more urgent. In this study, a novel kiwi fruit wine was successfully fermented using *Aspergillus niger* and *Aspergillus oryzae*, providing diversity for food development. Aging technology, as a hot research topic for the high-quality wine production, plays an important role in the aroma, color, stability, and clarification of fruit wine. The traditional way of aging in oak barrels is not only time-consuming, but also labor-intensive. Therefore, it is important to choose an appropriate and efficient aging method. Until now, few studies have been focused on the aging methods of newly developed kiwi fruit wines. The fast aging technique utilized in this study could help improve the quality of novel kiwi wine, shorten the aging time and save costs, which would provide significant reference for the development of food industry.

Author contributions

Yu Zhang: Writing - review and draft, methodology, resources & formal analysis. Qing Qiu: Writing - original draft, data curation. Yanghui Xu: Conceptualisation, softwarevalidation. Junying Zhu: Data analysis, methodology. Meng Yuan: Project administration, investigation..Maobin Chen: Supervision, resources & funding acquisition.

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