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Physicochemical and Microbial Properties of Korean Traditional Rice Wine, *Makgeolli*, Supplemented with Black Garlic Extracts during Fermentation

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Abstract

The purpose of this study was to elucidate the physicochemical and microbiological properties of Korean traditional rice wine, *Makgeolli*, supplemented with black garlic extract during fermentation. Black garlic extract was diluted with distilled water to produce 0.5% and 1.0% black garlic solutions. Those solutions were then used to make rice solutions which included 2 kg rice, 40 g *Nuruk* (a fermentation starter), and 14 g yeast. After being mixed, the rice solutions were fermented for 7 days in a water bath at 28°C. The alcohol contents of the control, 0.5% and 1.0% black garlic *Makgeolli* were 16.9, 16.0, and 16.2%, respectively. Total acidity, total soluble solids, and color increased throughout the fermentation process. There was an increase of microorganisms throughout the fermentation period in all the samples. Glucose was the highest free sugar, and succinic acid was the highest organic acid detected in all the samples. Thirty nine volatile compounds were detected in black garlic *Makgeolli*.

Key words: *Makgeolli*, Korean traditional rice wine, black garlic, fermentation

INTRODUCTION

The history of Korean rice wine, or *Makgeolli*, dates back to the period of Koguryeo, when Chinese literature recorded the manners and customs of consuming *Makgeolli* (1-3). *Makgeolli* is a popular alcoholic beverage and many different varieties of cocktail *Makgeollis* have been developed in Korea. *Makgeolli* has been brewed in the past using the fermentation starter *Nuruk*, cooked rice, yeasts and some medicinal plants or herbs (4,5). *Nuruk* was traditionally prepared by inoculating moistened ground wheat, or rice, with a mixture of airborne microorganisms such as fungi, yeasts, and a variety of other bacteria (6-10). The *Nuruk* is used to break down the starch so that the resulting sugars can be utilized by the yeast to create *Makgeolli*. However, there have been some problems, such as the lack of unique characteristics, inferior acceptability, and functionality in *Makgeolli* that resulted in its decline in popularity. Therefore, many research groups have been studying how to improve the quality of *Makgeollis* by examining factors such as microbial activities, functional characteristics, utilization of raw materials, manufacture processes, extension of shelf life and more (2,7,8,11,12).

For years, garlic, *Allium sativum*, has been used as a therapeutic medicinal agent. The use of garlic as a medicine has a long history. Drawings and carvings of garlic were found in Egyptian tombs, dating from 3700 BC, and its uses as a remedy for heart disease, tumors, and headaches were documented in the Egyptian *Codex Ebers*, dating from 1550 BC (13). Garlic has also been mentioned in the Bible and has been a traditional treatment in many countries (13). The use of garlic as a preventative and a treatment for a variety of diseases has been found at more than 3000 publications (14). Garlic has been shown to reduce the risk factors of cardiovascular diseases, such as lowering serum cholesterol and trigylcerides, inhibiting blood coagulation, improving blood circulation and lowering blood pressure (4). Also, it has been demonstrated that garlic, garlic extracts, and extract components have cancer preventative actions (13). However, people turn away from garlic because of its unpleasant odors and unpleasant gastric side effects.

Black garlic, or aged garlic, is an odorless product that results from prolonged fermentation of fresh garlic at room temperature. Black garlic has been reported to have an array of pharmacologic effects. Black garlic is highly bioavailable and has biological activities *in vitro* in both animals and humans. It contains water-soluble allyl amino acid derivatives, which account for most of its organosulfur content, stable lipid soluble allyl sulfides, flavonoids, saponins and essential and micronutrients (13). Due to its organosulfur and phenolic compounds, black garlic is noted for its potent antioxidant activity (13). A substantial amount of evidence shows that black garlic and its components inhibit the oxidative damage that results in a variety of diseases and aging.

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Also, black garlic has been noted for its effects in immunomodulation. Kyo et al. (14) reported that *Allium* vegetables, including garlic, inhibit the release of β-hexosaminidase, which is correlated with histamine release, and the data from that study suggests that black garlic may directly and/or indirectly modify the function of mast cells, basophils and activated T lymphocytes, which play a leading role in allergic cascade reactions including inflammation. This report also showed that black garlic had a variety of pharmacological effects, including tumor cell growth inhibition and chemopreventative effects (14). Therefore, the present study examined the physicochemical and microbial properties of *Makgeolli* supplemented with black garlic extracts during fermentation.

MATERIALS AND METHODS

Materials

Rice was purchased from a local market (Yongin, Korea), and black garlic extract was obtained from Nesco Ltd. (Gimhae, Korea). *Nuruk* and yeast were obtained from Korea Enzyme Co. (Hwaseong, Korea) and Saf-instant (Lesaffre, France), respectively.

Preparation of the control and black garlic *Makgeolli*

The preparation of the control and the black garlic *Makgeollis* are shown in Fig. 1. Two kg of rice were rinsed and soaked in tap water for 3 hr. After soaking, the rice was then drained of the water for 40 min and immediately steamed for 40 min. After the rice was steamed, the heat was turned off and the rice was left to sit for 20 min. The rice was quickly cooled by spreading out thinly on an aluminum pan. Once the rice was cooled, it was placed in a 10 L glass bottle, along with the *Nuruk* (40 g), yeast (14 g), and distilled water (3.5 L) and mixed. The top was secured with a plastic wrap and a rubber band and placed in a water bath at 28^{o}C and allowed to ferment for 7 days. Before investigating the physicochemical and microbial properties of each *Makgeolli*, the samples were filtered (Advantec 5B, Tokyo Roshi Kaisha, Ltd., Tokyo, Japan).

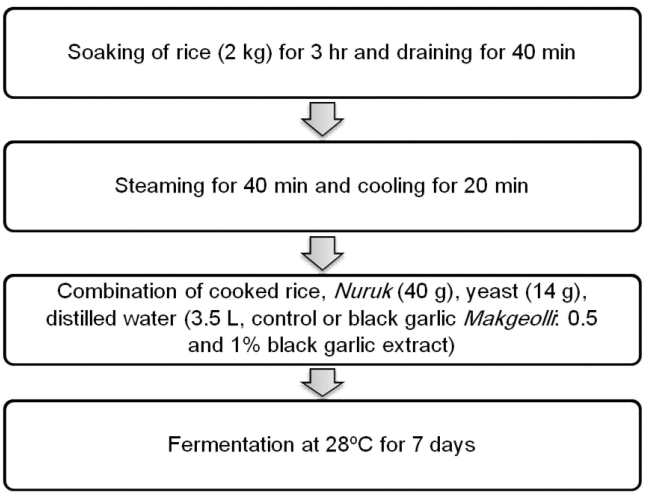

Fig. 1. Procedure for the control and black garlic *Makgeolli*.

Alcohol content

The alcohol content of *Makgeolli* was measured using the procedures adapted from Woo et al. (15). Briefly, 100 mL of the sample was run through a distiller until 70 mL was collected. The collected sample was set to 100 mL with distilled water and the alcohol content (%) was measured using an alcohol hydrometer. The alcohol-temperature correction table was used with the sample's alcohol content and temperature.

pH, total acidity, and total soluble solid content

The pH was measured using an Orion 3 Star pH Benchtop (Thermo Electron Co., Beverly, MA, USA). To investigate the total acidity, 10 mL of the samples were combined with the indicator (Bromothymol blue and neutral red) and titrated with a 0.1 N NaOH solution. The amount (mL) of NaOH used was expressed in a percentage equivalent to tartaric acid (16). The total soluble solid content was elucidated using a Digital refractometer (Model Dr-103L, Bellingham + Stanley Ltd., Tumbridge Wells, UK) and measured in Brix (^{o}Bx).

Color

The color values were obtained using the Tri-Stimulus Colorimeter (Model JC801, Color Techno System Co., Tokyo, Japan). They were calibrated with the original value with a standard plate (L=98.48, a=0.14, b=-0.41). Hunter's L (lightness), a (redness), and b (yellowness) values were obtained.

Total viable cells, lactic acid bacteria, and yeast

Total viable cells, lactic acid bacteria, and yeast counts were measured according to the Korean Food and Drug Association (16). The standard plate count was used on the pour plate method for each sample. Mixed samples were diluted using the 10 fold dilution with sterile saline (0.85% NaCl). In the total viable cell count, 1 mL of the diluted sample was mixed with 20 mL of PCA (plate count agar, Difco^{tm}, Lawrence, KA, USA) and incubated at 37^{o}C for 48 hr. In the lactic acid bacteria count, 1 mL of the diluted samples was mixed with 20 mL of BCP (bromocresol purple agar, Eiken Chemical, Tokyo, Japan) and incubated at 37^{o}C for 72 hr. In the yeast count, 1 mL of the diluted sample was mixed with 20 mL of PDA (potato dextrose agar, Difco^{tm}) and incubated at 25^{o}C for 120 hr. The number of microorganisms was counted by colony forming units (CFU).

Free sugar

Free sugar contents were evaluated using the method adapted from Kerem et al. (17). The samples were filtered through a 0.2 μm membrane filter and analyzed by HPLC system (JASCO Co., Tokyo, Japan) with an RI detector (RI-930). Using the external standard method, the standards (fructose, glucose, sucrose, maltose and lactose) were used and the curve was quantified. The HPLC conditions were set as follows: the flow rate of mobile phase (75% acetonitrile) through the carbohydrate high performance column (4.0 μm, 4.6×250 mm, Waters, Milford, MA, USA) was 1.4 mL/min and the column temperature was set at 35°C.

Organic acid

Organic acid contents were elucidated according to the procedure described by Kerem et al. (17). The samples were filtered through a 0.2 μm membrane filter and analyzed with an HPLC system (JASCO Co.) with a multiwavlength detector (MD-2010 Plus). Using the external standard method, the standards (oxalic acid, citric acid, tartaric acid, malic acid, succinic acid, lactic acid, and acetic acid) were used and the curve was quantified. The HPLC conditions were set as follows: the flow rate of mobile phase (0.1% phosphoric acid) through the Supelgel C-610H column (9 μm, 7.8×300 mm, Sigma, St. Louis, MO, USA) was 0.5 mL/min and the column temperature was set at 30°C.

Volatile compounds

Twenty mL of the samples were combined with 15 μL of octanal (the standard for the analysis of volatile compounds) in a 240 mL screwtop amber bottle (Sigma-Aldrich Co., St. Louis, MO, USA). The samples were placed in a 50°C dry oven for 10 min and the volatile compounds were collected. The volatile compounds were analyzed using the GC-GC GC/MS-QP2010 MS (Shimazhu, Kyoto, Japan), and the condition at which they were analyzed were as follows: GC was run with AT1 column (60 m×0.25 mm, Shimazhu), and the rate of temperature increase was 8°C/min between 5°C to 120°C, 12°C/min to 180°C, 15°C/min to 230°C. The carrier gas used was N_2 and the injection temperature and detection temperature were 200 and 250°C, respectively.

Statistical analysis

All statistical analyses were performed using SAS version 9.1 (SAS Institute Inc., Cary, NC, USA). Analysis of variance (ANOVA) was performed using the general linear models (GLM) procedure to determine significant differences among the samples. Means were compared by using Fisher's least significant difference (LSD) procedure. Significance was defined at the 5% level.

Table 1. Alcohol contents of the control and black garlic *Makgeolli* on day 7 of the fermentation period

Sample	Alcohol content (%)
Control	16.9
0.5% black garlic *Makgeolli*	16.0
1.0% black garlic *Makgeolli*	16.2

RESULTS AND DISCUSSION

Alcohol content

The alcohol contents of the control, 0.5% and 1.0% black garlic *Makgeollis* on the final fermentation day were 16.9, 16.0 and 16.2%, respectively (Table 1). The values for all the samples studied fell within the range of alcohol content of 15～18% for rice wines before dilution (18). The alcohol contents of the *Makgeollis* show the degree of fermentation throughout the fermentation process, and the alcohol content is one of the factors that affect the quality of *Takju* (19). Throughout the process of fermentation, starch is converted to glucose through hydrolysis and the glucose is then converted into alcohol by yeast. The by-product of this reaction is CO_2 and can be seen throughout the fermentation process as bubbles forming in the samples.

pH, total acidity, and total soluble solid content

The pH, total acidity, and total soluble solid contents of the control, 0.5% and 1.0% black garlic *Makgeollis* are seen in Fig. 2. The pH of the control, 0.5% and 1.0% black garlic *Makgeolli* were similar throughout the 7-day fermentation process. All three samples had a similar initial pH of around 6.0, and it was observed that the pH for all the samples decreased sharply on day 1 of the fermentation to around a pH value of 3.8 and slightly increased from then on to around a pH value of 4.5. Seo et al. (1) also reported a slight increase after the initial drop in the pH throughout fermentation period. The final pH values of the samples were similar to the pH levels of *Makgeollis* in other studies, which ranged from a pH of 3.4 to 4.5 due to the production of organic acids (1,4,18).

There were no considerable differences in the total acidity values between all the samples throughout the 7 day fermentation process. The total acidity values of all samples sharply increased on day 1 of the fermentation period and continued to slowly increase to around 0.3% by day 7. Generally speaking, microbes produce organic acids, which affect the total acidity of the *Makgeolli*, and the change of the total acidity is a factor for knowing the change of compounds in the *Makgeolli* (20). In addition, it is reported that the combination of the total acidity and the volatile compounds of the *Makgeolli* affect the quality of flavor in the *Makgeolli*

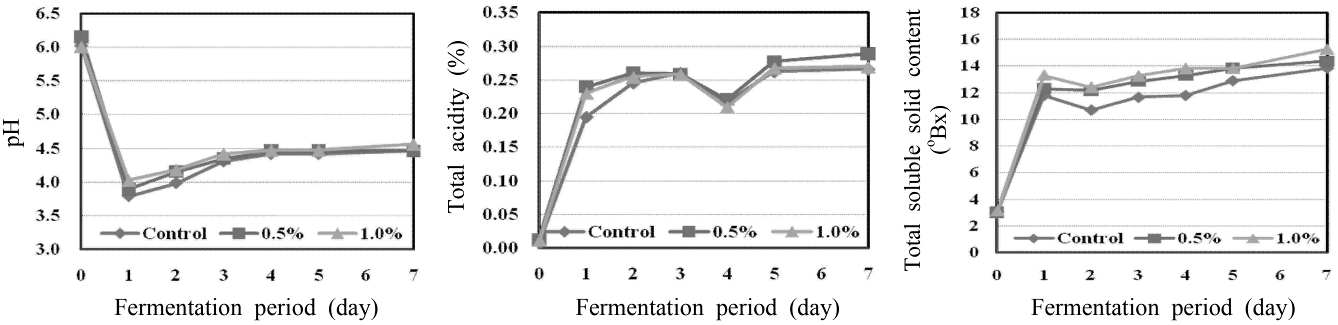

Fig. 2. pH values, total acidity values and total soluble solid contents of the control and black garlic *Makgeolli* throughout the 7-day fermentation period.

and also the shelf life (7).

The initial value of the total soluble solid content for the control, 0.5% and 1.0% black garlic *Makgeolli* was around 3.0°Brix. Brix is the measurement of refraction of soluble solids. Total soluble solid content for all the samples studied increased sharply on day 1 of the fermentation period to around a value of 12°Bx and steadily increased to a final value of 13.9, 14.4, and 15.3°Bx for the control, 0.5% and 1.0% black garlic *Makgeolli*, respectively. The total soluble solid contents show microbial reactions within the *Makgeolli*. Throughout fermentation, starch is converted to glucose; therefore, the increase in total soluble solids in the present study might indicate the increase of soluble sugar. For the pH, total acidity, and total soluble solid contents, the greatest change happened on day 1 of the fermentation period. This implies that most of the microbial activities may occur on the first day of the fermentation period.

Color

The values for the color analysis are shown in Table 2. As expected, the lightest *Makgeolli*, the sample with the highest L value, was the control, followed by the 0.5% black garlic *Makgeolli*, then the 1.0% black garlic *Makgeolli*. The 1.0% black garlic *Makgeolli* had the highest a and b values while the control had the lowest a and b values. Throughout fermentation, it can be seen that L, a and b values increased. The increase of the values was also seen in a study by Kim et al. (19) and Park et al. (21).

Microbial changes

The microbial count for the total viable cells, lactic acid bacteria, and yeast are shown in Table 3. The final total viable cell counts for the control, 0.5% and 1.0% black garlic *Makgeollis* were 2.88×10^{7}, 3.10×10^{7} and 3.20×10^{7} CFU/mL, respectively. The final lactic acid bacteria counts for the control, 0.5% and 1.0% black garlic *Makgeollis* were 1.50×10^{6}, 1.62×10^{6} and 1.80×10^{6} CFU/mL, respectively. The final yeast counts for the control, 0.5% and 1.0% black garlic *Makgeollis* were 1.90×10^{7}, 2.35×10^{7} and 2.50×10^{7} CFU/mL, respectively. There was an increase of microorganisms in all the samples after the 7-day fermentation. The increase of total microorganisms throughout the fermentation process was in agreement with the findings from Rhee et al. (22), who compared traditional (*Samhaeju*) and industrial (*Chongju*) rice wine brewing in Korea. Furthermore, Seo et al. (1), who identified the lactic acid bacteria involved in traditional Korean rice wine during fermentation, reported an increase of total microorganisms throughout fermentation.

Table 2. Color values (L, a and b) of the control and black garlic *Makgeolli* throughout the 7-day fermentation period

Sample	Fermentation period (day)	Color		
		L	a	b
Control	0	61.93	0.68	1.01
	1	64.83	1.75	2.80
	2	64.54	2.32	2.84
	3	64.70	2.67	2.80
	4	64.87	2.24	3.19
	7	66.20	2.95	4.84
0.5% black garlic *Makgeolli*	0	43.25	0.53	8.93
	1	43.93	1.99	9.75
	2	44.10	2.24	10.03
	3	44.38	2.14	10.90
	4	44.62	2.75	10.60
	7	47.66	3.61	11.01
1.0% black garlic *Makgeolli*	0	37.30	0.92	12.04
	1	37.83	2.63	12.68
	2	38.57	3.17	12.54
	3	38.44	3.07	13.17
	4	39.68	3.67	13.21
	7	41.73	4.16	13.95

Free sugar

Among all the free sugars studied in the present study, the major free sugar detected in all samples was glucose (Table 4). There was a significant decrease in the glucose content from day 1 of the fermentation period to day 7 in the samples. Glucose is an important part of the

Table 3. Microbial cell counts of the control and black garlic *Makgeollis* throughout the 7-day fermentation period (Unit: CFU/mL)

Sample	Microorganism	Fermentation period (day)			
		0	1	3	7
Control	Total viable cells	1.23×10^5	2.50×10^6	4.24×10^6	2.88×10^7
	Lactic acid bacteria	1.10×10^5	1.70×10^5	1.15×10^6	1.50×10^6
	Yeasts	1.26×10^5	2.38×10^6	1.56×10^7	1.90×10^7
0.5% black garlic *Makgeolli*	Total viable cells	3.25×10^5	4.50×10^6	5.20×10^6	3.10×10^7
	Lactic acid bacteria	1.71×10^5	3.70×10^5	1.03×10^6	1.62×10^6
	Yeasts	3.45×10^5	4.52×10^6	1.58×10^7	2.35×10^7
1.0% black garlic *Makgeolli*	Total viable cells	3.40×10^5	4.80×10^6	5.35×10^6	3.20×10^7
	Lactic acid bacteria	1.85×10^5	3.75×10^5	1.25×10^6	1.80×10^6
	Yeasts	3.58×10^5	4.90×10^6	1.70×10^7	2.50×10^7

Table 4. Free sugar contents of the control and black garlic *Makgeollis* on days 1 and 7 of the fermentation period (Unit: mg/mL)

Sample	Fermentation period (day)	Fructose	Glucose	Sucrose	Maltose	Lactose
Control	1	0.067^e	48.657^c	0.766^a	0.757^c	0.312^c
	7	0.047^f	30.961^e	0.272^c	1.240^b	0.434^b
0.5% black garlic *Makgeolli*	1	0.095^d	58.326^b	0.773^a	0.825^c	0.287^c
	7	0.109^c	43.160^d	0.318^b	1.447^a	0.798^a
1.0% black garlic *Makgeolli*	1	0.129^b	62.042^a	0.751^a	0.800^c	0.267^c
	7	0.158^a	47.887^c	0.314^b	1.520^a	0.811^a

Values with different letters within the same column differ significantly ($p<0.05$).

fermentation process due to the role it plays: it is the conversion of glucose that creates alcohol in the *Makgeolli*, and the production of glucose is through the hydrolysis of starch by amylase in *Nuruk*.

In the present study, the initial amount of glucose increased with the addition of black garlic extract. The 1.0% black garlic *Makgeolli* had a greater amount of glucose than the 0.5% black garlic *Makgeolli* and the control had the least initial amount of glucose. Glucose was also found to be a major free sugar in a study by Park et al. (23). The sucrose, maltose, and lactose contents in both the black garlic *Makgeollis* were significantly greater than those in the control on the final fermentation day. Overall, the addition of black garlic extract seemed to increase the final amount of free sugars in the *Makgeollis*. According to Kim et al. (19), fructose, glucose and maltose were found to be the major reducing sugar used by yeast to create alcohol and were associated with the particular taste of *Makgeolli.*

Organic acid

There were significant increases in the organic acid contents for tartaric acid, malic acid, succinic acid, lactic acid, and acetic acid throughout the fermentation period (Table 5). For all the samples, succinic acid contents were the highest among all the organic acids after the 7 day fermentation period. Lactic acid was found to be low, along with acetic acid, malic acid, tartaric acid, citric acid and oxalic acid, in all the samples. Though lactic acid was lower than expected, the production of organic acid may be dependent on several factors, including *Nur-*

Table 5. Organic acid contents of the control and black garlic *Makgeollis* on days 1 and 7 of the fermentation period (Unit: mg/mL)

Sample	Fermentation period (day)	Oxalic acid	Citric acid	Tartaric acid	Malic acid	Succinic acid	Lactic acid	Acetic acid
Control	1	0.002^a	0.218^a	0.045^{cd}	0.168^c	13.109^f	0.072^b	1.278^b
	7	0.002^a	0.212^a	0.063^{ab}	0.260^b	25.628^c	0.609^a	1.858^a
0.5% black garlic *Makgeolli*	1	0.003^a	0.197^a	0.041^d	0.189^c	15.893^e	0.048^b	1.348^b
	7	0.002^a	0.177^a	0.070^a	0.185^c	27.509^b	0.760^a	1.756^a
1.0% black garlic *Makgeolli*	1	0.003^a	0.232^a	0.051^{bcd}	0.171^c	16.552^d	0.047^b	1.449^b
	7	0.003^a	0.237^a	0.060^{abc}	0.298^a	27.969^a	0.706^a	1.804^a

Values with different letters within the same column differ significantly ($p<0.05$).

uk quality and fermentation conditions (6). The pattern of having high succinic acid and low lactic acid was also seen in a study by Rhee et al. (22), who suggest that the suppression of lactic acid and the increase of succinic acid may be due to the high colony forming units of yeast in the initial stage of brewing, which may suppress the acid forming bacteria.

Volatile compound

The relative peak areas of volatile compounds are shown in Table 6. A total of 39 volatile compounds were detected in the control and black garlic *Makgeollis*. Esters and alcohols were found to be the major components in the volatile compounds for all the samples. Among ester compounds, the relative peak areas of ethyl acetate were highest for all the samples. The control, 0.5, and 1.0% black garlic *Makgeollis* had 20.037, 15.447, and 26.470% ethyl acetate, respectively. The results were consistent with other studies (4,22). Ethyl acetate is a major volatile compound that gives *Makgeolli* its fruity taste (17). In a study by Kwon et al. (24), (E)-cinnamaldehyde, ethyl linoleate, ethyl linolenate, ethyl caprate, and ethyl palmitate were major esters found. The differences in the compounds detected, as compared with the present study, could be due to the differences in yeast and/or ingredients.

Table 6. Volatile compounds of the control and black garlic *Makgeollis* on day 7 of the fermentation period

(peak area %)

No	RI[1)]	Compounds	Sample		
			Control	0.5% black garlic *Makgeolli*	1.0% black garlic *Makgeolli*
1	362	Acetaldehyde	0.572	0.424	0.826
2	367	Methanol	0.165	0.091	0.040
3	373	Ethanol	3.050	2.772	1.402
4	600	Hexane	4.338	0.305	0.678
5	603	1-Propanol	4.208	0.296	6.488
6	623	Ethyl acetate	20.037	15.447	26.470
7	650	3-Methylbutanal	22.469	0.092	0.175
8	670	2-Methyl-1-propanol	0.057	30.301	11.253
9	676	Acetic acid	0.005	0.013	0.025
10	699	1-Butanol	0.018	0.100	0.870
11	727	Propanoic acid, ethyl ester	0.386	0.444	0.673
12	730	Acetic acid, propyl ester	0.076	0.261	0.057
13	770	3-Methyl-1-butanol	34.045	41.818	40.601
14	775	Ethyl isobutyrate	0.928	0.228	1.142
15	786	Acetic acid, 2-methylpropyl ester	0.325	0.894	0.304
16	790	3-Methyl-1-butanol	0.006	0.075	0.012
17	794	3-Methyl-1-hexanol	0.274	0.107	0.135
18	795	Hexanal	0.274	0.107	0.135
19	797	3-Methyl-1-butanol	0.274	0.086	0.086
20	799	Isobutyric acid	0.096	0.074	0.078
21	801	2,4-Dimethyl hexane	0.094	0.142	0.003
22	806	Butanoic acid, ethyl ester	0.530	0.473	0.598
23	831	2,4-Dimethyl heptane,	0.004	0.022	0.021
24	860	Ethyl 2-methyl butyrate	0.571	0.239	0.653
25	864	3-Ethoxy-1-propanol	0.019	0.007	0.653
26	870	4-Methyl octane	0.658	0.012	0.566
27	885	2-Methyl butyl acetate	0.278	0.543	0.209
28	901	Pentanoic acid, ethyl ester	0.028	0.013	0.030
29	961	Benzaldehyde	0.240	0.130	0.050
30	996	Octanal	5.052	3.818	4.891
31	1046	1,8-Cineole	0.009	0.020	0.004
32	1061	3-Ethyl-3-methyl heptane	0.001	0.034	0.009
33	1068	3,8-Dimethyl decane	0.010	0.033	0.002
34	1100	Undecane	0.033	0.033	0.023
35	1107	3,8-Dimethyl undecane	0.020	0.026	0.021
36	1124	Phenethyl alcohol	0.161	0.227	0.125
37	1195	Octanoic acid, ethyl ester	0.606	0.258	0.612
38	1799	Tetradecanoic acid, ethyl ester	0.014	0.004	0.018
39	1995	Hexadecanoic acid, ethyl ester	0.065	0.033	0.062
		Total	100	100	100

[1)]RI: Retention index.

As for the alcohols, there was a difference between the control and the black garlic *Makgeollis*. All the samples had 3-methyl-1-butanol as one of the major alcohol components (34.045, 41.818, and 40.601% for the control, 0.5, and 1.0% black garlic *Makgeolli*, respectively). However, the control also had 3-methylbutanol (22.469 %) for a major component and the 0.5 and 1.0% black garlic *Makgeolli* had 2-methyl-1-propanol (30.301 and 1.253, respectively). All of the major components seem to be yeast fermentation products (4). It was reported by Han et al. (8) that a greater content of 2-methyl-1-propanol than 3-methyl-1-butanol resulted in a low quality *Makgeolli*.

Acetaldehyde is also a volatile compound that was found in the *Makgeollis*. Acetaladehyde stimulates the smell and is also found in traditional *Soju* and *Chonju* as well (25). Shin et al. (25) analyzed 9 different alcohols, excluding ethanol, and reported that iso-amyl alcohol and iso-butyl alcohol were found to be the main alcohol. Lee et al. (26) studied the effect of different yeasts on eight different types of alcohol. Four out of 5 *Makgeollis* were observed to have iso-amyl alcohol as their major alcohol. The differences of detected volatile compounds in the present study may be due to the differences in the yeast and/or ingredients.

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