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ARTICLE

Quality characteristics of distilled alcohols prepared with different fermenting agents

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Abstract This study was performed to investigate the quality characteristics of distilled spirits made with different fermenting agents in copper distiller. The highest distillate yield was observed in the mashing made with fermenting agent A. The distillate made with fermenting agent A showed also significantly the highest level of ester and higher-alcohol concentration. In addition, the distilled spirit made with fermenting agent A indicated significantly higher preferences in appearance, smell, taste, quality, and overall acceptability than those of other agents. However, the aging in bottle for 6 months had no significant differences in sensory improvement in distilled spirits regardless in kind of fermenting agents. This study emphasizes the importance of rice *koji* as fermenting agent in distilled spirit prepared with rice and using with multistage distiller made of copper to improve aroma substances and yield ratio of distillate.

Keywords Copper distillation equipment · Distillation · Distilled spirits · Yeast strains · *Nuruk*

Introduction

The techniques of Korean distilled spirits were introduced from Yuan dynasty in late Koryo dynasty (Lee 1989). The research of Korean distilled spirits since 1980 focused on product development which is prepared using grain, sweet potato, and *nuruk*. Furthermore, the distilled spirits prepared by vaccum distiller showed various aroma compounds (Kim and Ahn 2001). Bae et al. (2007a) reported that the production for high quality in Andong soju *nuruk* needs 4.0 ~ 5.5 cm thickness and 3-week maturation without extraneous yeast addition. Bae et al. (2007b) noted identification and fermentation characteristics of lactic acid bacteria isolated from the fermentation broth of Korean traditional distilled spirit, Andong soju. Bae et al. (2003) indicated the effect of the amount of water on the yield and flavor of Korean distilled spirit based on rice and corn starch and showed that 250 % of water addition was the most economical and optimal brewing condition. Ryu and Kim (2002) reported the esterification of alcohols with organic acids during distilled spirit distillation. Min et al. (1994) indicated the distillation phenomenon by distillation condition at different pressure, different reflux ratio, and different column conditions. Volatile components and fusel oils of soju and mashes brewed by Korean traditional method such as Andong soju were determined by sensory descriptive analysis (In et al. 1995a; Jee et al. 2008). Quality and physicochemical characteristics of Korean folk distilled spirits were determined using principal components analysis (PCA). As the result, less volatile ethyl succinate and ethyl pelargonate were present in Korean folk sojues, while volatile ethyl acetate and ethyl butyrate were in Chinese distilled spirit (In et al. 1995b; Lee et al. 2012, 1994a, b). Min et al. (1992) reported changes in compositions of liquor fraction distilled from Samilju with various distillation conditions. Park et al. (2010) noted effects of sweet potato cultivars and *koji* types on general properties and volatile flavor compounds in sweet potato soju. The fusel oil and the volatile compounds of two potato sojues, one of which was produced with the

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traditional distillation apparatus and the other with the reduced pressure distillation system, were examined where the fusel oil contents were high in the potato soju that was distilled under pressure. Kim et al. (1991a, b) reported changes in components of hongju mash fermented by different methods. Cho et al. (2013) reported quality characteristics of fruit spirits from copper distillation apparatus. This research conducted to examine the quality characteristics of distilled alcohol prepared with different fermenting agents.

Materials and methods

Fermenting agents and mashing schedule

Traditional *nuruk*(songhak), improved *nuruk*(Korean enzyme), uncooked rice fermenting *nuruk*(Korean enzyme), and rice *koji*(dongsan koji) were used to propagate and mash as fermenting agents (Table 1), where, for same fermenting condition, the different amount of fermenting agent between mashing methods was added due to difference of saccharification power in each fermenting agent, namely the saccharification power of traditional *nuruk* has on average ten times stronger than rice *nuruk*. The saccharification power of the improved *nuruk* and the uncooked rice fermenting *nuruk* have on average fifty times stronger than rice *nuruk*.

Propagation, fermentation, and distillation

The rice used for propagation and fermentation was variety of Chuchung in Gyunggi Province, Korea. The rice for propagation by test plot was washed five times and soaked in water. After drain off water, the rice was crushed. The condition for propagation and fermentation by test plot is shown in Table 1. The distiller used in this study was multistage distiller made of copper which was heated by indirect system. During the distillation, the mash was agitated for preventing burning. The distillate was classed as head, body, and tail. The time for head, body, and tail distillation is 40, 160, and 30 min, respectively.

Table 1 Schedule of mashing by fermenting agents

	Classify	A	B	C	D
Propagation (2 ~ 3 days)	Rice		0.3 kg	0.3 kg	0.3 kg
	Rice *koji*	0.3 kg	–	–	–
	Traditional *nuruk*	–	30 g	–	–
	Improved *nuruk*	–	–	6 g	–
	Uncooked rice fermenting *nuruk*	–	–	–	6 g
	Lactic acid	3.5 mL	3.5 mL	3.5 mL	3.5 mL
	Distillation yeast	6 g	6 g	6 g	6 g
	Water	0.45 L	0.45 L	0.45 L	0.45 L
1st fermentation (4 days)	Rice	–	2.7 kg	2.7 kg	2.7 kg
	Rice *koji*	2.7 kg	–	–	–
	Traditional *nuruk*	–	270 g	–	–
	Improved *nuruk*	–	–	54 g	–
	Uncooked rice fermenting *nuruk*	–	–	–	54 g
	Water	4 L	4 L	4 L	4 L
2nd fermentation (12 days)	Rice	7 kg	7 kg	7 kg	7 kg
	Rice *koji*	100 g	–	–	–
	Traditional *nuruk*	–	10 g	–	–
	Improved *nuruk*	–	–	2 g	–
	Uncooked rice fermenting *nuruk*	–	–	–	2 g
	Water	11.2 L	11.2 L	11.2 L	11.2 L
Period of fermentation		18 days			
Fermentation temperature		25 °C			

A Rice *koji*(dongsan *koji*), *B* traditional *nuruk*(songhak), *C* improved *nuruk*(Korean enzyme), *D* uncooked rice fermenting *nuruk*(Korean enzyme). The mashing of each agent was conducted from a single preparation

Chemical analysis

The pH during fermentation was measured by a pH meter(model Orion 720A, Beverly, MA, USA). Soluble solid concentrations (°Brix) were measured using a refractometer model H-50(Atago, Torrance, CA, USA). For the determination of acidity, samples (100 mL) were titrated with 1–2 drops of phenolphthalein to pH 8.3 with 0.1 N NaOH. Total titratable acidity was calculated by the following equation using consumed amounts (mL) of 0.1 N NaOH at the end-point (pink color).

$$\text{Acidity}(\%) = [(\text{ml of } 0.1\ \text{N NaOH}) \times (\text{NNaOH}) \times 0.075\ (\text{succinic acid coefficient}) \times 100]/\text{mL sample}$$

Volatile compounds analysis

The volatile compounds were isolated using a head-space auto sampler (Agilent 7694E; Agilent Technologies, CA, USA) and a gas chromatography–mass spectrometry (GC–MS) (HP 6890 N; Hewlett-Packard, PA, USA) was used for analysis. The isolation of the volatile compounds was carried out for each vial at 80 °C for 30 min, with the injection loop at 90 °C and the temperature transfer line at 100 °C. GC–MS analysis was carried out using a Hewlett-Packard 6890 N Network gas chromatograph coupled to a Hewlett-Packard 5973 quadrupole mass spectrometer which was equipped with a DB-FFAP fused silica capillary column (30 m × 0.25 mm ID and 0.25 µm film thickness; J&W Scientific Inc., Folsom, CA, USA). The carrier gas was ultrapure helium with a flow rate of 1 ml/min and the pressure was at 7.5 kPa. The oven temperature of the GC was held at 50 °C for 5 min and then set to 150 °C at 2 °C/min at the rate 3 °C/min. Both the injector and the transfer line were heated at 250 and 280 °C. The ionization voltage applied was 70 eV and the mass spectra were obtained in a scan range from 40 to 350 m/z. All mass spectra were also compared with the data system library database.

Sensory evaluation

The sensory characteristics of samples were evaluated by 20-membered panels. The preferences for appearance, smell, taste, quality, and overall acceptability were determined by 5-point scale (1 dislike very much; 2 dislike moderately; 3 like slightly; 4 like moderately; and 5 like very much). The sensory evaluation panel included professors and students of University. The sensory panel consisted of 11 women and nine men, aged from 20 to 40 years.

Statistical analysis

Significant differences (sensory and GC–MS analyses) among samples for each of the parameters analyzed were assessed with a one-way analysis of variance (ANOVA) using the SPSS Version 12.0 K statistical package for Windows (SPSS, Chicago, USA).

Results and discussion

Chemical properties of mashing brewed with different fermenting agents

The chemical properties of mashings brewed with different fermenting agents are shown in Table 2 where alcohol content (%), pH, soluble solid concentration (°Brix), and acidity(%) analysis results are presented. All mashings prepared with different fermenting agents showed similar fermenting patterns for 16 days, therefore they increased during fermentation period, which is similar to the results of previous study (Kim et al. 2010). However, the mashing made with fermenting agent A indicated the highest alcohol content (18.4 %) after 6 days of fermentation. This can be attributed that the mashing made with fermenting agent A had a higher fermenting ability and alcohol tolerance than those of the other fermenting agents. And total acidity showed same tendency like alcohol, which is the same as the results of Choi et al. (2013). The pH levels among the mashings were slightly changed along the fermentation period like Cho et al. (2013) reported, from 4.16 to 3.49 in the mashing made fermenting agent D, and from 4.25 to 3.68 or 3.56 in mashings made fermenting agents B and A, and from 4.14 to 3.68 in the mashing prepared fermenting agent C, respectively. Thus, the highest pH (4.17) was found in the mashing made with fermenting agent C, whereas the pH of mashings made with the other fermenting agents was 3.79–3.86 at 16 days of fermentation. Lee et al. (2013) reported that there was the correlation between soluble solid concentration and alcoholic fermentation period. In the present study, the soluble solid concentration (°Brix) among the mashings decreased during the alcoholic fermentation period where the mashing made with fermenting agent A indicated the lowest concentration at the final days of fermentation. The total acidity content increased during alcoholic fermentation period and showed the similar total acidity change patterns. This finding is consistent with that of Cho et al. (2013). The highest total acidity was observed in the mashing made with fermenting agent D (5.1 %), whereas the mashing

Table 2 Chemical content of mashing brewed with different fermenting agents

Fermenting agents	Compounds	Days								
		0	2	4	6	8	10	12	14	16
A	Alcohol(%)	0	1.1 ± 0.0	3.9 ± 0.1	6.9 ± 0.2	10.8 ± 0.1	13.0 ± 0.2	15.8 ± 0.2	17.1 ± 0.1	18.4 ± 0.2
	Acidity(%)	0	1.1 ± 0.0	3.7 ± 0.2	4.1 ± 0.1	4.2 ± 0.0	4.4 ± 0.2	4.6 ± 0.1	4.7 ± 0.0	4.7 ± 0.1
	pH	4.25 ± 0.1	3.56 ± 0.1	3.78 ± 0.1	3.87 ± 0.2	3.89 ± 0.1	3.88 ± 0.1	3.80 ± 0.2	3.78 ± 0.1	3.79 ± 0.1
	Soluble solid concentration(°Brix)	–	28.6 ± 0.1	17,9 ± 0.0	14.5 ± 0.1	12.0 ± 0.0	11.8 ± 0.1	11.0 ± 0.0	10.3 ± 0.1	9.0 ± 0.0
B	Alcohol(%)	0	1.3 ± 0.1	4.8 ± 0.2	5.5 ± 0.2	9.4 ± 0.1	12.3 ± 0.3	14.6 ± 0.2	16.5 ± 0.5	17.6 ± 0.4
	Acidity(%)	0	1.2 ± 0.0	3.5 ± 0.1	4.0 ± 0.2	4.2 ± 0.1	4.6 ± 0.1	4.7 ± 0.2	4.6 ± 0.2	4.8 ± 0.1
	pH	4.25 ± 0.2	3.68 ± 0.1	3.80 ± 0.1	3.90 ± 0.2	3.89 ± 0.1	3.91 ± 0.1	3.90 ± 0.2	3.88 ± 0.2	3.89 ± 0.3
	Soluble solid concentration(°Brix)	–	28.2 ± 0.3	21.1 ± 0.2	17.8 ± 0.1	16.0 ± 0.1	13.8 ± 0.2	11.6 ± 0.2	11.0 ± 0.1	10.6 ± 0.1
C	Alcohol(%)	0	1.2 ± 0.1	3.7 ± 0.1	5.8 ± 0.2	10.1 ± 0.1	12.1 ± 0.1	13.9 ± 0.1	15.4 ± 0.2	16.7 ± 0.2
	Acidity(%)	0	0.8 ± 0.0	1.6 ± 0.0	3.1 ± 0.1	3.8 ± 0.1	4.2 ± 0.1	4.2 ± 0.1	4.2 ± 0.0	4.2 ± 0.1
	pH	4.14 ± 0.1	3.68 ± 0.1	3.70 ± 0.1	3.72 ± 0.2	3.80 ± 0.1	3.89 ± 0.0	4.01 ± 0.1	4.11 ± 0.0	4.17 ± 0.1
	Soluble solid concentration(°Brix)	–	26.3 ± 0.1	20.1 ± 0.2	17.9 ± 0.2	15.1 ± 0.3	14.0 ± 0.2	12.3 ± 0.3	11.1 ± 0.1	10.9 ± 0.1
D	Alcohol(%)	0	1.3 ± 0.1	4.5 ± 0.0	6.5 ± 0.2	10.4 ± 1.0	12.4 ± 0.9	13.4 ± 9.8	14.5 ± 0.4	15.8 ± 0.9
	Acidity(%)	0	0.9 ± 0.1	1.9 ± 0.2	3.0 ± 0.2	3.4 ± 0.1	4.1 ± 0.2	4.5 ± 0.3	4.9 ± 0.2	5.1 ± 0.2
	pH	4.16 ± 0.1	3.59 ± 0.2	3.49 ± 0.1	4.03 ± 0.1	3.81 ± 0.2	3.76 ± 0.1	3.81 ± 0.3	3.84 ± 0.2	3.86 ± 0.1
	Soluble solid concentration(°Brix)	–	27.3 ± 1.0	20.2 ± 1.1	18.9 ± 0.9	16.1 ± 0.9	15.1 ± 1.0	13.4 ± 0.7	12.1 ± 0.5	11.4 ± 0.4

A Rice *koji*(dongsan *koji*), *B* traditional *nuruk*(songhak), *C* improved *nuruk*(Korean enzyme), *D* uncooked rice fermenting *nuruk*(Korean enzyme)

Results are expressed as mean ± SD ($n = 3$)

prepared with fermenting agent C indicated the lowest concentration of total acidity (4.2 %). The fermentation pattern by mashings prepared with rice was similar to previous results (Lee et al. 2010; Son et al. 2011).

The results of the distillate yield after distillation of mashing are shown in Table 3. The distillate yield was calculated taking into account the alcohol content after fermentation, mashing volume, distillation ratio of body (95 %), and expected alcohol content (45 %) like Choi et al. (2013) reported. The highest distillate yield was observed in the mashing made with fermenting agent A (8.70 L), followed by mashing prepared with fermenting agent B (8.47 L), C (8.24 L), and D (7.46 L), respectively. Thus, the mashing made with fermenting agent A had a positive effect not only on fermentation ratio but also on distillate ratio.

The results of yield ratio of distillate on body are shown in Table 4. The yield ratio of distillate was calculated in consideration of alcohol content as 100 % pure alcohol, alcohol content of body, and yield of body. The yield ratio of distillate was calculated taking into account the distillation ratio and fermentation ratio like Lee et al. (2013) reported. The highest yield ratio of distillate was observed in the mashing made with fermenting agent A (75.65 %), whereas the mashing prepared with fermenting agent D indicated the lowest yield ratio of distillate (62.74 %) because of lower fermentation ratio and distillation ratio. Furthermore, the distillation ratio (95.6 %) of the mashing made with fermenting agent A was similar to the highest value in previous results (Arctander 1969; Lee et al. 2006), while the mashings prepared with other agents indicated the lower yield ratio of distillate than agent A in previous results (Arctander 1969). This result means that the distillation spirit prepared with fermenting agent A indicated best cost competitiveness than the other distillation spirits made with fermentation agent B, C, and D.

The aroma of distillation spirits is an important characteristic that contributes to quality of distillation spirits and created by alcohols, esters, aldehydes, ethers, and organic acid compounds (Kim et al. 1991a, b; Choi et al. 2013; Lee et al. 2013). Figures 1, 2, 3, 4, 5, 6, 7, 8 represent volatile compounds (ethyl acetate and higher alcohols) after 6-month aging of distillates made with different fermenting agents. The main component of esters is ethyl acetate which gives banana-like aroma and unpalatable at higher amounts (Cho et al. 2013). With regard to the esters, ethyl acetate, lactic acid ethyl ester, *n*-octanoic acid ethyl ester, ethyl *n*-caprate, and succinic acid diethyl ester were detected in the four distillates after 0 month. Acetic acid isobutyl ester and ethyl *n*-caproate were additionally detected in the distillate made with fermenting agent C (data not shown). The distillate made with fermenting agent A showed significantly the highest level (157.5 mg/L) of ethyl acetate compared with the other distillates. Among the volatile compounds, higher alcohols such as *n*-propanol, i-butanol, and i-amyl alcohol were detected in the four distillates and *n*-butanol was additionally detected in the distillate fermenting A (Figs. 5, 6, 7, 8) which also indicated the highest levels of higher-alcohol concentration (3,071 mg/L). This value was higher than that reported by Yoo et al. (2010). In this result, synthesis of ethyl acetate and higher alcohols was significantly enhanced in the distillate made with fermenting agent A compared with the other distillates, and this result strongly suggests that the fermentation prepared with rice *koji* and distillation yeast had a positive effect on increasing of aroma substances such as ethyl acetate and higher alcohols. This finding is similar to that reported by Choi et al. (2013) and Cho et al. (2013). The changes of aroma compounds during the 6-month aging in stain steel tank among the four distillates were also investigated in this study where the distillates were monitored and analyzed every 2 months. As shown in Figs. 1, 2, 3, 4, 5, 6, 7, 8, the difference among the four distillates with regard to aroma compounds in 0 month was observed where the distillate made with fermenting agent A indicated the highest ethyl acetate and higher alcohols content. This tendency was maintained until 6 month. It means that the aroma compounds among the 4 distillates decreased slightly during the aging. This result strongly suggests that the aging in bottle had almost no effect on distillates regarding aroma compounds.

The volatile compounds of 40 % distilled spirits made with different fermenting agents are shown in Table 5. In total, 13 compounds were detected, including seven esters,

Table 3 Distillate yield after distillation of mashing made with different fermenting agents

Fermenting agents	Alcohol after fermentation (v/v %)	Mashing volume (L)	Distillation ratio of body (%)	Expected alcohol content (v/v %)	Distillation Vol. of head (L)	Distillation Vol. of body (L)	Head + body (L)
A	18.4	24.7	95	45	0.26	8.44	8.70
B	17.6	25.0	95	45	0.25	8.22	8.47
C	17.2	24.9	95	45	0.25	8.00	8.24
D	16.2	26.3	95	45	0.22	7.23	7.46

A Rice *koji*(dongsan *koji*), *B* traditional *nuruk*(songhak), *C* improved *nuruk*(Korean enzyme), *D* uncooked rice fermenting *nuruk*(Korean enzyme)

Table 4 Yield ratio of distillate in body after distillation

Classify	Alcohol (v/v %) (as 100 % pure alcohol)	Alcohol of body (v/v %)	Yield of body (L)	Distillation ratio (%)	Fermentation ratio (%)	Yield ratio of distillate (%)
A	4.12	46.7	8.44	95.6	79.1	75.65
B	4.01	46.3	8.22	94.8	77.0	73.03
C	3.90	46.2	8.00	94.6	74.9	70.90
D	3.53	45.2	7.23	92.6	67.8	62.74

A Rice *koji*(dongsan *koji*), *B* traditional *nuruk*(songhak), *C* improved *nuruk*(Korean enzyme), *D* uncooked rice fermenting *nuruk*(Korean enzyme)

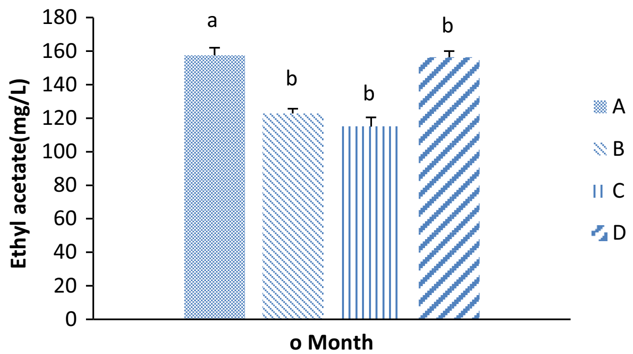

Fig. 1 Ethyl acetate concentration for 0 month aging of distillate made with different fermenting agents *A* rice *koji*(dongsan *koji*), *B* traditional *nuruk*(songhak), *C* improved *nuruk*(Korean enzyme), *D* uncooked rice fermenting *nuruk*(Korean enzyme). Results are expressed as mean ± SD ($n = 3$); $^{a–b}$means with the same letter are not significantly difference by duncan's multiple range test ($p < 0.05$)

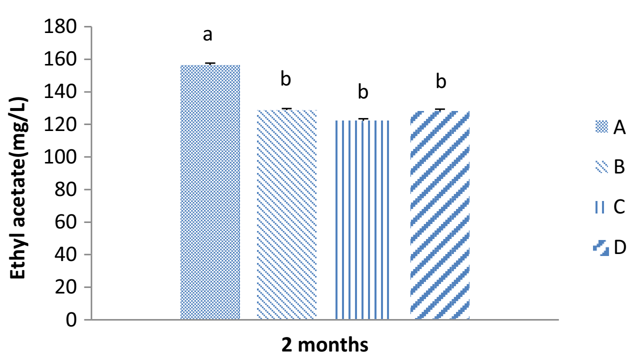

Fig. 2 Ethyl acetate concentration for 2-month aging of distillate made with different fermenting agents *A* rice *koji*(dongsan *koji*), *B* traditional *nuruk*(songhak), *C* improved *nuruk*(Korean enzyme), *D* uncooked rice fermenting *nuruk*(Korean enzyme). Results are expressed as mean ± SD ($n = 3$); $^{a–b}$means with the same letter are not significantly difference by duncan's multiple range test ($p < 0.05$)

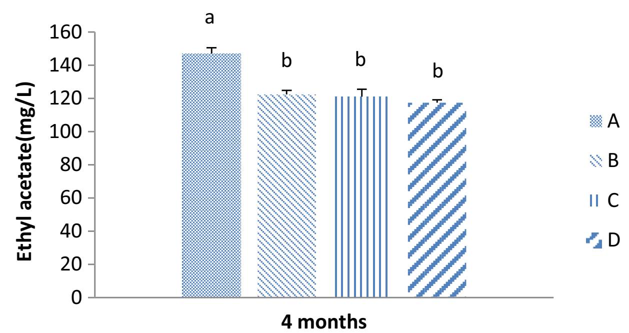

Fig. 3 Ethyl acetate concentration for 4-month aging of distillate made with different fermenting agents *A* rice *koji*(dongsan *koji*), *B* traditional *nuruk*(songhak), *C* improved *nuruk*(Korean enzyme), *D* uncooked rice fermenting *nuruk*(Korean enzyme). Results are expressed as mean ± SD ($n = 3$); $^{a–b}$means with the same letter are not significantly difference by duncan's multiple range test ($p < 0.05$)

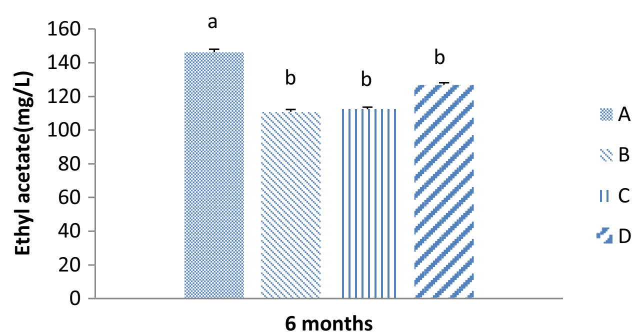

Fig. 4 Ethyl acetate concentration for 6-month aging of distillate made with different fermenting agents *A* rice *koji*(dongsan *koji*), *B* traditional *nuruk*(songhak), *C* improved *nuruk*(Korean enzyme), *D* uncooked rice fermenting *nuruk*(Korean enzyme). Results are expressed as mean ± SD ($n = 3$); $^{a–c}$means with the same letter are not significantly difference by duncan's multiple range test ($p < 0.05$)

four higher alcohols, and two other compounds. Ethyl acetate concentration was highest (192.2 mg/L) in the distilled spirit made with fermenting agent A, and lowest (108.4 mg/L) in the distilled spirit prepared with fermenting agent B. Isoamyl alcohol was highest (1,355.2 mg/L) in the distilled spirit made with fermenting agent A, followed by the distilled spirit made with fermenting agent C (1,146.7 mg/L). The distilled spirit made with fermenting agent A also showed the highest level of *n*-propanol (488.5 mg/L) and i-butanol (802.9 mg/L),

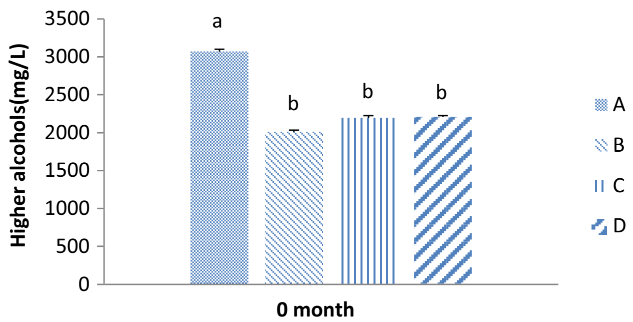

Fig. 5 Higher alcohols concentration for 0-month aging of distillate made with different fermenting agents *A* rice *koji*(dongsan *koji*), b traditional *nuruk*(songhak), *C* improved *nuruk*(Korean enzyme), *D* uncooked rice fermenting *nuruk*(Korean enzyme). Results are expressed as mean ± SD ($n = 3$); $^{a–b}$means with the same letter are not significantly difference by duncan's multiple range test ($p < 0.05$)

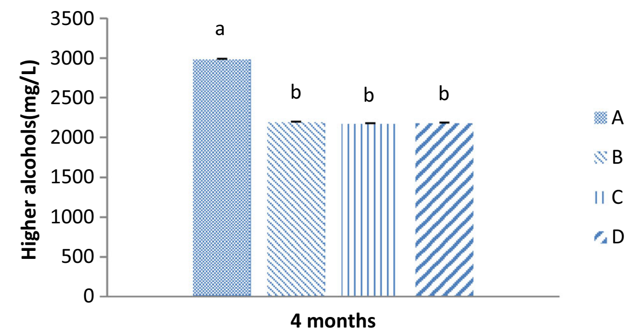

Fig. 7 Higher alcohols concentration for 4-month aging of distillate made with different fermenting agents *A* rice *koji*(dongsan *koji*), *B* traditional *nuruk*(songhak), *C* improved *nuruk*(Korean enzyme), *D* uncooked rice fermenting *nuruk*(Korean enzyme). Results are expressed as mean ± SD ($n = 3$); $^{a–b}$means with the same letter are not significantly difference by duncan's multiple range test ($p < 0.05$)

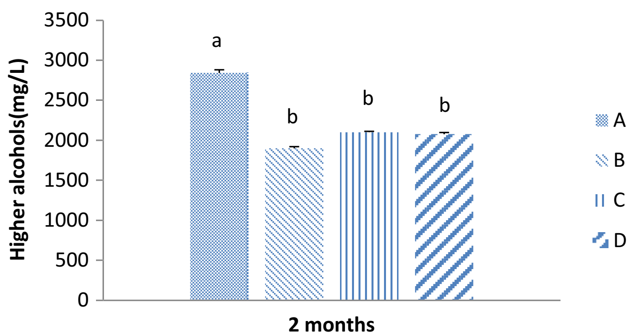

Fig. 6 Higher alcohols concentration for 2-month aging of distillate made with different fermenting agents *A* rice *koji*(dongsan *koji*), *B* traditional *nuruk*(songhak), *C* improved *nuruk*(Korean enzyme), *D* uncooked rice fermenting *nuruk*(Korean enzyme). Results are expressed as mean ± SD ($n = 3$); $^{a–b}$means with the same letter are not significantly difference by duncan's multiple range test ($p < 0.05$)

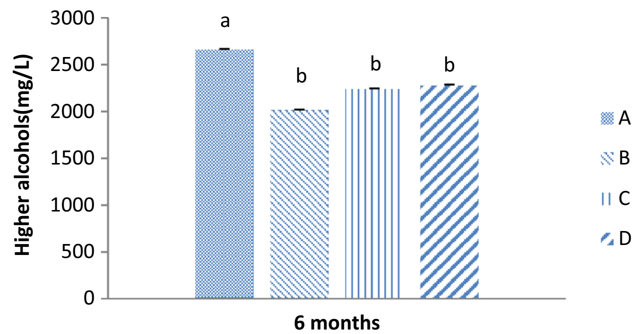

Fig. 8 Higher alcohols concentration for 6-month aging of distillate made with different fermenting agents *A* rice *koji*(dongsan *koji*), *B* traditional *nuruk*(songhak), *C* improved *nuruk*(Korean enzyme), *D* uncooked rice fermenting *nuruk*(Korean enzyme). Results are expressed as mean ± SD ($n = 3$); $^{a–b}$means with the same letter are not significantly difference by duncan's multiple range test ($p < 0.05$)

respectively. Ethyl acetate and i-amyl alcohol detected were the most abundant compounds and similar to the results of previous study (In et al. 1995a). The majority of esters are formed by esterification during yeast fermentation. It is known that high level of ethyl acetate is unpalatable at higher concentrations (Yoo et al. 2010). Isoamyl alcohol is an important compound in high-quality alcoholic beverage, strongly impacting the flavor and taste by adding a sweet, banana-like aroma (Lee et al. 2013).

The results of the four types of distilled spirits evaluated by a panel were shown in Table 6. The preferences for appearance, smell, taste, quality, and overall acceptability were determined by a 5-point scale. The distilled spirit made with fermenting agent A indicated significantly higher preferences in appearance, smell, taste, quality, and overall acceptability. In this study, the panel's preference for the sensory evaluation can be explained from the above-mentioned results of volatile compounds analysis in Tables 4 and 5; the distilled spirit made with fermenting agent A had high sensory score according to the enhanced ester and higher-alcohol concentration. However, this study revealed that the aging in glass for 6 months had no differences in sensory improvement in distilled spirits regardless of kind of fermenting agents.

To this day, the alcohol industry has used vacuum pot distiller made of stainless steel for distillation after fermentation of mashing like Bae et al. (2007a) reported. This study emphasizes the importance of rice *koji* as fermenting agent in distilled spirit prepared with rice. In addition, the using of multistage distiller made of copper instead of vacuum pot distiller was effective means to improve yield ratio and aroma of distillate.

Table 5 Volatile compounds of 40 % distilled spirits made with different fermenting agents

	Volatile compounds	A	B	C	D
Esters	Ethyl acetate (mg/L)	192.2 ± 2.1[a]	108.4 ± 3.4[b]	132.2 ± 2.1[b]	112.8 ± 1.3[b]
	Acetic acid isobutyl ester (μ/L)	0.0 ± 0.0	0.0 ± 0.0	2.7 ± 0.1	0.0 ± 0.0
	Ethyl *n*-caproate (μℓ/L)	0.0 ± 0.0	0.0 ± 0.0	2.8 ± 0.1	1.0 ± 0.0
	Lactic acid ethyl ester (μℓ/L)	20.8 ± 0.9[a]	24.7 ± 0.7[a]	6.8 ± 0.2[b]	11.8 ± 0.5[b]
	n-octanoic acid ethyl ester (μℓ/L)	4.5 ± 0.1[a]	6.0 ± 0.1[a]	9.2 ± 0.6[a]	7.1 ± 0.1[a]
	Ethyl *n*-caprate (μℓ/L)	7.6 ± 0.2[a]	8.7 ± 0.3[a]	19.3 ± 0.9[b]	10.6 ± 0.3[a]
	Succinic acid diethyl ester (μℓ/L)	10.3 ± 0.6[a]	30.8 ± 1.2[c]	2.5 ± 0.1[b]	3.4 ± 0.0[b]
Higher alcohols	*n*-propanol (mg/L)	488.5 ± 6.4[a]	219.7 ± 11.2[b]	343.3 ± 10.2 [b]	256.4 ± 9.1[b]
	i-butanol (mg/L)	802.9 ± 19.2[a]	660.7 ± 14.6[b]	607.9 ± 11.5[b]	449.2 ± 10.0[c]
	n-butanol (mg/L)	0.0 ± 0.0	0.0 ± 0.0	4.1 ± 0.0	34.8 ± 1.4
	i-amyl alcohol (mg/L)	1,355.2 ± 17.1[a]	937.9 ± 26.7[b]	1,072.8 ± 16.8[b]	1,046.7 ± 24.1[b]
	Sum of higher alcohols	2,646.6 ± 16.3[a]	1,818.3 ± 19.2[b]	2,028.1 ± 11.1[b]	1,787.1 ± 10.6[b]
Other compounds	Methyl alcohol (mg/L)	13.9 ± 0.4[a]	20.5 ± 1.1[b]	13.6 ± 0.3[a]	0.0 ± 0.0
	Furfural (μℓ/L)	3.9 ± 0.1[a]	4.5 ± 0.2[a]	0.0 ± 0.0	2.2 ± 0.1[a]

A Rice *koji*(dongsan *koji*), *B* traditional *nuruk*(songhak), *C* improved *nuruk*(Korean enzyme), *D* uncooked rice fermenting *nuruk*(Korean enzyme)

Results are expressed as mean ± SD ($n = 3$); $^{a\text{–}c}$means with the same letter in column are not significantly difference by duncan's multiple range test ($p < 0.05$)

Table 6 Sensory evaluation of 40 % distilled spirits made with different fermenting agents

Attributes of distillate	Distillation spirits			
	A	B	C	D
Appearance	74 ± 1.2[a]	72 ± 2.0[a]	74 ± 1.1[a]	70 ± 1.0[a]
Smell	149 ± 1.3[a]	128 ± 1.2[b]	121 ± 1.0[b]	124 ± 1.1[b]
Taste	159 ± 2.0[a]	129 ± 2.3[b]	132 ± 1.4[b]	108 ± 1.2[c]
Quality	86 ± 1.1[a]	64 ± 1.0[b]	70 ± 1.0[b]	62 ± 2.1[b]
Overall acceptability	468 ± 2.3[a]	393 ± 2.3[b]	397 ± 3.2[b]	364 ± 2.3[b]

A Rice *koji*(dongsan *koji*), *B t*raditional *nuruk*(songhak), *C* improved *nuruk*(Korean enzyme), *D* uncooked rice fermenting *nuruk*(Korean enzyme)

Results are expressed as mean ± SD ($n = 3$); $^{a\text{–}c}$means with the same letter in column are not significantly difference by duncan's multiple range test ($p < 0.05$)

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