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Restoration of Traditional Korean Nuruk and Analysis of the Brewing Characteristics

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In this study, a total of 58 different kinds of nuruk (a traditional Korean fermentation starter) were prepared, including 46 kinds of restored nuruk from ancient documents. Each nuruk was evaluated by analysis of its saccharification power, and the enzyme activities of glucoamylase, α-amylase, β-amylase, protease, and β-glucanase. The range of saccharification power (sp) of the restored nuruk ranged between 85 and 565 sp. The diastatic enzymes, α-amylase, β-amylase, and glucoamylase, were significantly correlated to the saccharification power value; conversely, β-glucanase and protease did not have a correlative relationship with saccarification power. In addition, their brewing properties on chemical and organoleptic aspects of traditional alcoholic beverage production were compared. Each raw and supplementary material contained in nuruk showed its own unique characteristics on Korean alcoholic beverage brewing. For the first time, in this study, the traditional Korean nuruk types mentioned in ancient documents were restored using modernized production methods, and also characterized based on their brewing properties. Our results could be utilized as a basis for further study of traditional alcoholic beverages and their valuable microorganisms.

Keywords: Nuruk, traditional alcoholic beverages, brewing, koji, gokja, fermentation

Introduction

Nuruk is a traditional Korean fermentation starter that is used to produce starch-based alcoholic beverages, using various cereals as raw material. Starch is the main ingredient used for alcohol fermentation, and is first hydrolyzed into glucose through the saccahrification process by fungi. At this time, nuruk is used as a fermentation agent and is an important raw material for the brewing process. Nuruk is also called “gokja” in Korea, and this fermentation starter has microorganisms such as fungi, yeast, and lactic acid bacteria, *etc*. that naturally inoculate and multiply in it. Traditionally, nuruk has been made from several grains such as wheat, barley, rice, and millet, and grains are used as the major raw materials for nuruk and alcohol beverage processing. The brewing method of traditional Korean alcoholic beverages utilizes nuruk to cause saccharification and fermentation of starch to occur simultaneously and thus differs from the Japanese koji, which is artificially inoculated into the sterile starch medium. In other words, nuruk and koji can be distinguished by the presence or absence of the wild-type yeast, lactic acid bacteria, and environmentally derived microorganisms. Thus, it is a reason why yeast and lactic acid bacteria should be added when brewing processing using koji, which differs significantly from Korea’s unique brewing method. Nuruk should be added during the fermentation process in order to exert its function. Interestingly, alcoholic beverages fermented with nuruk have more flavor and bouquet than those fermented with koji.

Nuruk shows significant variation in its shape, and in the brewing and fermentation methods, which are dependent on the unique climate in each area. It has been shown that nuruk can be adapted to particular a geographical area and climate. With the development of molded nuruk in China and the dispersed koji in Japan, Korean traditional nuruk has been developed with a wide variety of materials and shapes. For its development, the humidity and the amount of sunshine strongly influences the width and thickness of nuruk originating from different areas in Korea, from the wide and thin nuruk in the mountainous areas, to the thick and small nuruk in the flat areas. In addition, the main raw materials used to produce nuruk vary widely according to the production area.

Therefore, it is worthy to note that the characteristics of Korean traditional nuruk are based on its diversity. However, the use of traditional nuruk in a variety of brewing method is dwindling owing to the recent increase in the use of Japanese koji [1]. In Korea, research on traditional nuruk was started in the early 1900s by the Japanese, but had not actively progressed until recently. However, recent research studies on the production of some traditional nuruk [2−4], nuruk-derived microorganisms [5−9], production of the traditional Korean alcoholic beverages using nuruk [10−13], and its physiological function [14−17] have been reported for scientific investigations of the traditional nuruk. In addition, research on the nuruk microbial communities [18−20] as well as the metabolite analysis of nuruk [20] was recently performed. Although a variety of nuruk are found in Korea, only a few types are produced and used in modern beverage production. Thus, this study aimed to scientifically identify the characteristics of traditional nuruk by restoring the manufacturing methods recorded in ancient documents, such as *Sanllimgyeongje*, *Limwonsibyukji*, *Gyugonsiuibang* (also known as *Umsikdimibang*), *etc*. The present study also aimed to characterize nuruk that has been used in the brewing of traditional Korean alcoholic beverages by examining older literature published in Korea such as *QiMin YaoShu* and the *Compendium of Material Medica*. This study also presents for the first time the use of Korean traditional nuruk production methods described in ancient documents together with production methods supported by modern technologies. These observations will be utilized as a basis for further studies on traditional Korean alcoholic beverages and their valuable uses.

Materials and Methods

Restoration of Traditional Nuruk

Forty-six kinds of traditional nuruk were restored by modernizing the production methods described in ancient documents. The documents related to food are *Gyugonsiuibang* (also known as *Umsikdimibang*), *Jungbo Sanlimgyungjae*, *Limwonsibyukji*, *QiMin YaoShu*, the *Compendium of Material Medica*, *Gyuhap Chongseo*, and *Donguibogam*. The manufacturing methods for 46 kinds of traditional nuruk were developed using modern methology and modified for a feasible production method. These 46 restored traditional nuruk include various raw materials, such as 6 types of barley, 12 types of whole wheat, 11 types of flour, 10 types of glutinous rice, 3 types of non-glutinous rice, and 1 type of buckwheat flour. The detailed restoration methods are shown in Table 1. In addition, seven kinds of commercially available traditional nuruk and five kinds of self-manufactured nuruk that were produced by the brewer were prepared.

Saccharification Power Analysis of Nuruk

Saccharification power (sp) represents the index of how much soluble starch can be enzymatically converted to simpler sugars by diastatic enzymes in nuruk. The saccharification power of various types of nuruk was measured according to the modified alcoholic beverage regulations of the National Tax Administration. Briefly, 5 ml of 2% soluble starch solution and 3.0 ml of acetate buffer solution (pH 5.0) were mixed and the mixture was pre-incubated at 55°C for 10 min. Then, 1.0 ml of enzyme solution (1.0 g nuruk extracted with 1% sodium chloride solution at 30°C for 3 h) was added, and the mixture was fixed for 60 min to saccharify the starch. The reaction was stopped by the addition of 1.0 ml of 0.5 N sodium hydroxide. A 0.2 ml aliquot of the reaction mixture and 0.6 ml of dinitrosalicylic acid reagent were combined in a separate tube and incubated at 100°C for 5 min. The absorbance at 550 nm was then measured following the addition of 3.2 ml of water. The percentage of total glucose content derived from 1.0 g of soluble starch by 1.0 g of nuruk enzyme was expressed as the sp.

Analysis of Nuruk Enzyme Activities

The enzyme activities of traditional nuruk were analyzed using a Megazyme kit (Megazyme Inc., Ireland). The absorbance obtained by adding substrate to the nuruk extract was expressed as enzyme units/g nuruk. For protease activity, produced peptides were quantified using a colorimetric method by utilizing the trinitrobenzene sulfonic acid reagent to react with the free amino group generated during protein hydrolysis. The proteolytic activity was measured versus the equivalent activity of trypsin (a representative protease) as the standard.

Production of Alcoholic Beverages Based on Korean Traditional Nuruk

The brewing properties of each type of nuruk were identified using a secondary addition method, which involved the addition of supplementary materials after 7 days of fermentation. The first brewing was prepared by combining 300 g of steamed white rice powder, 100 g of nuruk, and 900 ml of water followed by fermentation at 23°C for 7 days. The second brewing was processed by adding 700 g of steamed rice and 600 ml of water to the first fermentation, followed by a second round of fermentation at 23°C for 14 days. All brewing processes were carried out in triplicates for each type of nuruk.

Table 1. Reproduction materials and process method of traditional nuruk.

No.	Name	Materials	Production
1	JuKokBangMun	Wheat bran Straw	1. Mix well the wheat bran with adding water 2. Mold, followed by fermentation with straw for 20 days
2	ChuMoGok	Whole barley	1. Grind whole barley into rough powder 2. Collect only rough powder by sieve 3. Mix well the powder with adding water 4. Mold, followed by fermentation with straw for 20 days
3	OMeKiGok	Whole barley Wheat flour	1. Mix wheat flour with soaked barley powder 2. Mold, followed by fermentation with straw and paper
4	JukGok-1	Whole wheat flour Rice powder	1. Collect wheat flour without wheat bran using sieving 2. Mix well the prepared flour and rice porridge 3. Mold, followed by fermentation
5	JukGok-2	Whole wheat flour Glutinous rice flour Water	1. Collect wheat flour without wheat bran using sieving 2. Mix well the prepared flour and glutinous rice porridge 3. Mold, followed by fermentation
6	KongByungGok	Whole wheat	1. Grind whole wheat into rough powder 2. Collect only rough powder by sieve 3. Mix well the powder with adding water 4. Mold, followed by fermentation
7	Gok-1	Whole wheat Castor leaves	1. Grind whole wheat and collect only wheat bran 2. Mix well the wheat bran with adding water 3. Mold and wrap up with castor leaf 4. Fermentation in a straw or straw bag
8	MyunGok-1	Whole wheat Paper mulberry leaves	1. Grind whole wheat into rough powder 2. Mix powder with water from washing wheat 3. Mold and wrap up with paper mulberry leaf 4. Fermentation in a straw
9	SinGok-1	Whole barley	1. Steam 1/3 of barley and roast another 1/3 of barley 2. Grind all prepared barley and mix well with water 3. Mold and pierce a hole, followed by fermentation
10	JinjuchunchuGok	Whole wheat	1. Roast whole barley and grind roasted barley 2. Mix powder with water 3. Mold, followed by fermentation
11	YeoGok-1	Glutinous rice Masculine wormwood	1. Steam glutinous rice and cool down 2. Mold and wrap up with masculine wormwood 3. Strap the wrapped nuruk on with straw 4. Ferment, followed by drying in the sun
12	SeolhangGok	Wheat, Glutinous rice BunGok wormwood	1. Grind wheat and soaked glutinous rice and remove tough skin 2. Mold all of the prepared powder, followed by fermentation with wormwood
13	YeonHwaGok-1	Glutinous rice Cocklebur leaves	1. Steam glutinous rice and prepare to hard-boiled rice 2. Make flat the rice following fermentation on cocklebur leaves for 7–14 days
14	BackGok-1	Wheat flour Glutinous rice Paper mulberry leaves Straw rope	1. Mix well the wheat powder with glutinous rice and sift 2. Mold and wrap up with paper mulberry leaves 3. Fasten the molded materials with straw rope, followed by fermentation for 50 days
15	BackGok-1	Wheat flour Glutinous rice flour	1. Mix wheat flour with glutinous rice and sift 2. Mold and fasten the molded materials with straw rope, followed by fermentation for 50 days

Table 1. Continued.

No.	Name	Materials	Production
16	YeoGok-2	Whole wheat flour Masculine wormwood Straw	1. Steam whole wheat flour and cool it down 2. Mold and wrap up with wormwood 3. Fasten the molded materials with straw rope and hang them up during fermentation for 50 days
17	BunGok	White wheat flour	1. Prepare white wheat flour from whole wheat 2. Mold, followed by fermentation
18	ByungGok	White wheat flour Straw	1. Prepare white wheat flour from whole wheat 2. Mold as round-shaped 3. Fermentation with straw and also expose to the sun
19	IWhaJuGok	Rice Straw	1. Soak rice and grind into fine powder 2. Mold as round duck's egg size 3. Fermentation in a straw for 21 days
20	IWhaGok	Rice Pine leaves	1. Soak rice and grind into fine powder and mold as round egg size 2. Fermentation with a straw in a paper bag 3. Expose nuruk to the sun after fermentation
21	JoGokBeok	Wheat Mung beans	1. Prepare tough wheat powder and skin from wheat 2. Grind mung beans and remove skin 3. Wash grinded mung beans and dry 4. Mold prepared wheat powder with mung beans 5. Fermentation in a straw for 20 days
22	HyangOnGok-1	Barley Mung beans	1. Prepare tough barley powder from whole barley 2. Grind soaked mung beans and remove skin 3. Prepare mung bean juice and mix well with barley powder 4. Mold, followed by fermentation
23	HyangOnGok-2	Whole wheat Whole barley Mung beans	1. Prepare tough wheat powder from whole wheat 2. Grind soaked mung beans and remove skin 3. Prepare mung bean juice from grinded mung bean 4. Mix well with wheat and barley powder 5. Mold, followed by fermentation
24	BakSuHwan-DongJuGok	Glutinous rice Skinless mung beans Pine leaves	1. Steam skinless mung beans and cool it down 2. Soak glutinous rice and grind into powder 3. Mix well the mung beans with glutinous rice powder 4. Mold as round duck's egg size 5. Fermentation in pine leaves
25	Nebubijeongok	Wheat Mung beans Brown rice	1. Grind mung beans and collect with skins 2. Soak bean skins in water 3. Grind brown rice and mix with mung beans and wheat 4. Mix well with water-soaked beans 5. Mold, followed by fermentation for 60 days
26	NokMiJuGok	Glutinous rice Skinless mung beans Pine leaves	1. Steam skinless mung beans and cool it down 2. Soak glutinous rice and grind into powder 3. Mix mung beans with glutinous rice powder and pound 4. Mold as round duck's egg size 5. Fermentation in pine leaves for 20 days
27	NokDuGok	Rice Skinless mung beans Dried wormwood	1. Soak skinless mung beans and rice overnight 2. Grind prepared mung beans and rice into powder 3. Mold, followed by fermentation in a dried wormwood
28	Gok-2	Whole wheat Wheat flour Mung bean juice Lotus leaves, Straw	1. Grind soaked mung beans 2. Prepare tough wheat powder from whole wheat 3. Mix well the whole wheat powder with mung bean juice

Table 1. Continued.

No.	Name	Materials	Production
29	MiGok-1	Glutinous rice Smartweed juice Pine leaves	1. Grind soaked glutinous rice into powder 2. Mix well the rice powder with smartweed juice 3. Mold as round shape, followed by fermentation in pine leaves for 30 days
30	MyunGok-2	Whole barley Mung beans Smartweed, Straw Dried wormwood	1. Grind dried whole barley into tough powder 2. Soak mung beans and smartweed 3. Prepare juice from mung beans and smartweed 4. Mix barley powder and prepared juice 5. Mold, followed by fermentation in the straw and dried wormwood for 21 days
31	Gok-3	Wheat bran Mung beans Mung beans Smartweed leaves Paper mulberry leaves Nut pine leaves	1. Soak mung beans and smartweed leaves, followed by preparing juice from them 2. Mix wheat bran with prepared juice
32	YoGok	Glutinous rice Wheat flour Water pepper	1. Boil water pepper down for a long time and prepare juice 2. Soak glutinous rice in smartweed juice overnight and mix with wheat flour 3. Fermentation paper materials in paper bag 4. Hang the sealed paper bag for 2 months
33	DaeJuBackTaGok	Whole wheat Plant medicine extract (Wormwood, Mulberry leaves, Cocklebur leaves)	1. Wash whole wheat, followed by sundrying 2. Steam 2/3 of prepared wheat, followed by grinding 3. Grind 1/3 of prepared wheat without steaming 4. Prepare plant medicine extract juice 5. Mix all prepared wheat in extract juice 6. Mold, followed by fermentation for 28 days
34	BackRyoGok	Barley Cocklebur leaves Masculine wormwood Straw	1. Wash whole barley, followed by sundrying 2. Steam 2/3 of prepared barley, followed by grinding 3. Grind 1/3 of prepared barley without steaming 4. Prepare grinded cocklebur extract juice 5. Mold and wrap up with cocklebur leaves and also tie with straw, followed by fermentation for 21 days
35	YangNeungGok	Wheat flour Glutinous rice Akane, Honey, Straw	1. Grind soaked glutinous rice and mix with equivalent wheat flour, akane, honey 2. Mold, followed by fermentation and sundrying
36	BackJuGok-1	Glutinous rice Medicinal herbs Wormwood juice	1. Grind washed glutinous rice and plant medicine into fine powder 2. Mix all prepared materials and mold as round shape, followed by fermentation in the straw
37	BackJuGok-2	Glutinous rice, nuruk Medicinal herbs Wormwood juice Balloon flower roots	1. Grind washed glutinous rice and plant medicine into fine powder 2. Mix all prepared materials with wormwood juice 3. Mold as round shape and make a small hole in the center and coat with dried balloon flower roots powder 4. Fermentation in the straw for 20 days and dry
38	ManJeonHangJuGok	Wheat flour Glutinous rice flour Oriental melon Lotus, *Angelica dahurica* root, Elecampane, White sandal wood, *Agastache rugosa*, *Glycyrrhiza uralensis*, *Atractylodes macrocephala*	1. Grind all plant materials into powder 2. Prepare oriental melon and lotus juice 3. Mix wheat powder and glutinous rice powder in oriental melon and lotus juice 4. Mold and wrap each lump up with paper 5. Hang the prepared paper for 49 days

Table 1. Continued.

No.	Name	Materials	Production
39	JeongHwaGok	Whole wheat Ginger juice (starch removed)	1. Grind wheat into fine powder and remove wheat skin 2. Mix prepared wheat powder with ginger juice 3. Mold and tie with straw, followed by fermentation for 21 days
40	YeonHwaGok-2	Mung beans (skinless) Glutinous rice *Atractylodes macrocephala* Akane	1. Grind washed glutinous rice and soaked mung beans 2. Mix all prepared materials with *Atractylodes macrocephala* and akane juice 3. Mold and wrap up with lotus leaves, followed by fermentation in wormwood
41	DongYangJuGok	Wheat flour Apricot seed, Root of *Aconitum,* Mung beans, Elecampane, Cinnamon, Cocklebur, Plum blossom, Cocklebur leaves, Water pepper	1. Grind skinless peach seeds and apricot seeds 2. Soak elecampane, cinnamon cocklebur, and plum blossom for 7 days and strain extracted water 3. Prepare cocklebur and cocklebur leaves juice 4. Boil mung beans in the extracted water 5. Mix wheat flour with boiled mung beans 6. Mold, followed by fermentation in the straw
42	MiGok-2	Glutinous rice Water pepper juice Paper mulberry leaves	1. Grind washed and soaked glutinous rice 2. Mix rice powder with water pepper juice and mold as round and flat shape 3. Wrap up with paper mulberry leaves and tie with straw, followed by fermentation for 49 days
43	ShinGok-1	Buckwheat flour Cocklebur juice Water pepper juice Wormwood juice Peach seed powder Red beans Paper mulberry leaves	1. Grind buckwheat and peach seeds into powder 2. Pound boiled red beans and mix all prepared materials 3. Mold, followed by fermentation in paper mulberry leaves
44	ShinGok-2	Wheat flour Wormwood juice Red beans, Peach seed Cocklebur juice Water pepper juice	1. Pound boiled red beans and grind peach seeds 2. Mix wheat with red bean and peach seed powder and add wormwood, cocklebur, and water pepper juice 3. Mold and wrap up with paper mulberry leaves, followed by fermentation
45	ShinGok-3	Wheat Cocklebur juice	1. Dry washed wheat in the sun 2. Divide wheat into three equal parts and grind each parts of steamed, roasted, and raw wheat 3. Mix prepared wheat powder with cocklebur juice 4. Mold, followed by fermentation for 26 days
46	HaDongShinGok	Barley, Mulberry Cocklebur, Wormwood	1. Dry washed barley in the sun and grind each parts of steamed (3/10), roasted (6/10), and raw (1/10) barley 2. Prepare water-added mulberry, cocklebur, and wormwood juice 3. Mix prepared wheat powder with extracted water 4. Mold and make a hole in the center, followed by fermentation for 28 days

Physicochemical Properties Analysis

The pH and Brix values were measured with a pH meter (D-50; Horiba, Japan) and a Brix meter (Pocket PAL1; Atago, Japan), respectively. Total acidity was controlled by titration with 0.1N NaOH standard solution, and the amount of NaOH solution added was used to calculate the equivalent acetic acid in each sample. Alcohol content was measured as described in the Liquor Tax Act (2016). One hundred milliliters of sample was mixed with 100 ml of distilled water in an Erlenmeyer flask. The Erlenmeyer flask was connected to a distilling apparatus with a cooler and the solution was distilled to 80 ml of volume. Distilled water was added to the distillate to a total volume of 100 ml, and the alcohol content (%) of the solution was measured with a density meter (DMA 4500A; Anton Paar GmbH, Austria).

Sensory Analysis

The samples were evaluated using a 5-point scale for acidity, bitterness, sweetness, smoothness, body, astringency, sweet flavor, acid flavor, and overall quality. Ten well-trained panelists scored each attribute on a scale of 1 to 5, where 1 was weakest or unacceptable, and 5 was strongest or most acceptable.

Statistical Analysis

Principle component analysis was conducted by using SIMCA P+ ver. 12.0 (Umetrics, Sweden) in order to identify the correlation between the sensory characteristics of traditional Korean alcoholic beverages produced using different types of nuruk.

Results and Discussion

Reproduction of Traditional Nuruk

Traditional nuruk restored on the basis of ancient documents are shown in Fig. 1. It was verified that most of each nuruk has its unique color derived from the raw materials, and in some cases, fungal hyphae on their surface. The shapes of traditional nuruk are different according to a lot of environmental conditions; they are usually circular, disc-shaped, square, or with holes. Normally, well-fermented nuruk has a clean surface, with no cracks and no offensive flavor. It is generally accepted that the quality of nuruk cannot be determined only by its saccharification and fermentation power; rather, it should also be determined by complex quality factors, such as flavor and taste, in the resulting alcoholic beverages. Thus, it is difficult to judge the quality of nuruk by its appearance alone. Moreover, it is even more difficult to judge the quality of alcoholic beverages fermented with supplementary materials-containing nuruk, such as medicinal herbs or pharmaceutical plants. However, generally, it has been known that nuruk without an offensive flavor and epiphytic mold spores also tends to have a strong saccharification power and is considered to be superior nuruk [21].

Enzymatic Activities of Nuruk

There are a variety of microorganisms in fermented nuruk, and enzymes secreted by these microorganisms differ depending on the type of wild microorganism. According to the earlier investigation of the enzymatic activities of traditional nuruk, the saccharification power of nuruk was 1.39, which was slightly lower than the saccharification power of malt (1.5 sp) and significantly lower than that of Chinese nuruk (11.1 sp) [22]. This suggests that the quality of nuruk used in these studies was poor. According to Lee's [23] study, it has been reported that the analysis results on saccharification power of Backguk produced by *Aspergillus kawachii* and Hwangguk produced by *Asp. oryzae,* which were being used in all parts of Korea in the mid-1900s. The saccharification power values were the highest in Bungok (791 sp), followed by Gokja (421 sp), Hwangguk (226 sp), and Backguk (195 sp). Forty-six different kinds of restored nuruk were enzymatically analyzed in this study. The saccharification power of 14 kinds of commercial and self-produced nuruk and their measured enzyme activities are presented in Table 2. The range of saccharification powers of the restored nuruk was 85 to 565 sp. nuruks with the highest saccharification power were shown in Bungok (565.5 sp), Naebubijeon (565.2 sp), and Migok (547.9 sp). These results indicate that some restored nuruk have a significantly higher saccharification power value than Jinjugokja (Keumkang wheat, 460.1 sp), which is a commercial nuruk, and ShinDaRi nuruk (477.2 sp), which is a self-produced nuruk. The higher α-amylase activities of restored nuruk were recorded in Bungok (65.53 U/g) and Byunggok (53.2 U/g), which were higher than JinjuGokja (26−38 U/g) showing a high activity among the collected nuruk. Bungok had a higher α-amylase activity than a self-manufactured nuruk, Igasubul (55.49 U/g). In addition, the β-amylase activity was the highest in Jinjugokja, which is commercially available, and protease activity was the highest in self-manufactured Igauubul (10.32 μg/ml), followed by restored Omegigok (9.9 μg/ml). The activities of α-amylase and β-amylase were significantly correlated to saccharification power value ($p < 0.001$). The correlation between the glucoamylase activity and saccharification power was also confirmed ($p < 0.05$). On the other hand, the activities of β-glucanase and protease in traditional Nuruk did not correlate with saccharification power value.

Brewing Characteristics of Nuruk

The physicochemical analysis results of traditional Korean alcoholic beverages, produced in order to find out their brewing properties, are presented in Table 3. The alcohol content and fermentation rates of beverages produced by restored nuruk were 15.0% and 67.1%, respectively, and those of commercial nuruk were 15.2% and 68.0%, respectively, suggesting no differences between the two groups. The sensory characteristics of alcoholic beverages produced by traditional Korean nuruks were also investigated. Multivariate analysis was carried out on the sensory evaluation results derived from each attribute, including sweetness, acidity, body, smoothness, bitterness, astringency, and sweet flavor, by selecting 28 types of beverages with high sensory preferences for each raw material (Fig. 2). Nuruk with whole wheat as the main

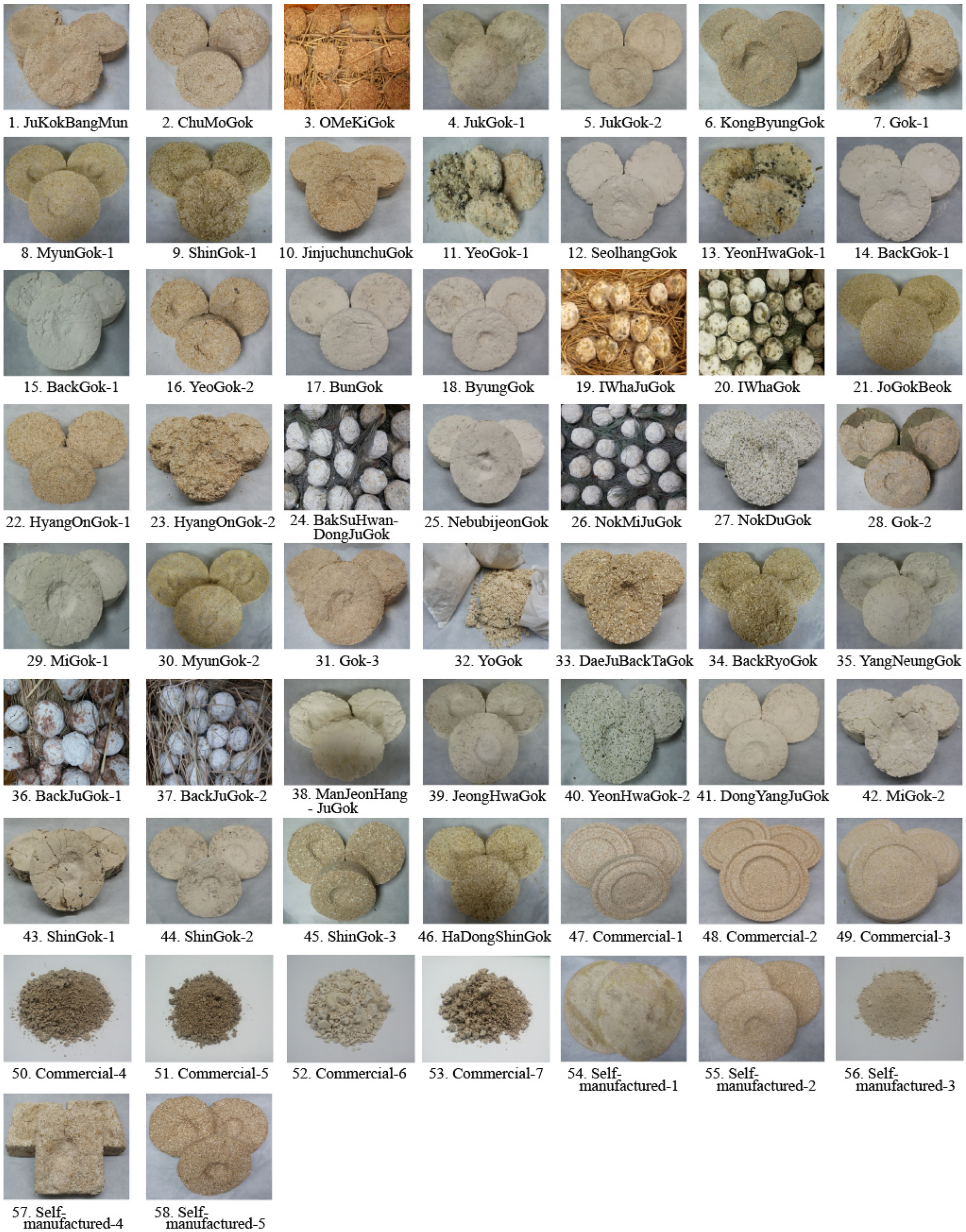

Fig. 1. Appearances of restored traditional and commercial nuruks.

Table 2. Saccharification power and enzyme activities of Korean traditional nuruks.

No.	Nuruk	Saccharification power	Enzyme activity[a]				
			α-Amylase (U/g Nuruk)	β-Amylase (U/g Nuruk)	Protease (μg/ml trypsin)	β-Glucanase (U/g Nuruk)	Glucoamylase (U/g Nuruk)
1	JuKokBangMun	325.43 ± 50.97	1.58 ± 0.36	2.82 ± 0.17	1.53 ± 0.09	0.048 ± 0.008	0.16 ± 0.10
2	ChuMoGok	194.82 ± 0.10	17.42 ± 1.10	1.44 ± 0.76	1.57 ± 0.07	0.191 ± 0.020	0.17 ± 0.06
3	OMeKiGok	151.44 ± 16.11	17.84 ± 0.86	0.72 ± 0.13	9.90 ± 7.28	0.348 ± 0.022	0.48 ± 0.29
4	JukGok-1	319.34 ± 76.83	10.75 ± 1.81	3.13 ± 0.25	1.77 ± 0.41	0.042 ± 0.001	0.75 ± 0.58
5	JukGok-2	265.93 ± 18.50	6.72 ± 1.02	3.35 ± 0.52	1.61 ± 0.10	0.041 ± 0.004	0.43 ± 0.57
6	KongByungGok	318.83 ± 17.74	39.07 ± 6.70	4.58 ± 0.36	1.42 ± 0.87	0.108 ± 0.014	1.05 ± 0.09
7	Gok-1	346.75 ± 14.76	1.47 ± 0.43	3.83 ± 0.24	1.48 ± 0.36	0.046 ± 0.016	0.05 ± 0.02
8	MyunGok-1	292.22 ± 12.14	8.76 ± 1.77	4.37 ± 0.11	1.75 ± 0.22	0.057 ± 0.008	0.27 ± 0.06
9	SinGok-1	137.46 ± 10.23	6.0251.29	1.01 ± 0.31	2.31 ± 0.61	0.187 ± 0.017	0.16 ± 0.05
10	JinjuchunchuGok	163.53 ± 0.09	16.61 ± 2.85	0.18 ± 0.02	1.76 ± 0.31	0.091 ± 0.007	0.31 ± 0.06
11	YeoGok-1	85.53 ± 6.12	9.45 ± 6.73	0.05 ± 0.01	1.51 ± 0.25	0.082 ± 0.011	0.15 ± 0.03
12	SeolhangGok	211.52 ± 18.21	2.73 ± 1.82	1.83 ± 0.30	1.63 ± 0.07	0.049 ± 0.007	0.04 ± 0.00
13	YeonHwaGok-1	112.67 ± 18.18	2.44 ± 0.57	0.05 ± 0.02	1.43 ± 0.13	0.161 ± 0.052	0.29 ± 0.08
14	BackGok-1	150.76 ± 11.76	11.47 ± 4.56	1.31 ± 0.07	1.59 ± 0.05	0.047 ± 0.008	0.04 ± 0.04
15	BackGok-1	164.61 ± 4.65	46.09 ± 10.57	1.56 ± 0.20	2.08 ± 0.09	0.047 ± 0.010	0.13 ± 0.01
16	YeoGok-2	370.09 ± 6.05	0.96 ± 0.05	2.74 ± 0.13	1.63 ± 0.08	0.043 ± 0.003	0.03 ± 0.01
17	BunGok	565.54 ± 22.67	65.53 ± 2.42	3.80 ± 0.34	1.82 ± 0.13	0.121 ± 0.043	0.50 ± 0.03
18	ByungGok	395.20 ± 47.49	53.20 ± 7.42	4.58 ± 0.19	1.61 ± 0.26	0.070 ± 0.013	0.37 ± 0.12
19	IWhaJuGok	241.07 ± 12.05	29.61 ± 3.60	0.09 ± 0.02	1.69 ± 0.30	0.334 ± 0.023	0.45 ± 0.06
20	IWhaGok	351.28 ± 10.74	19.90 ± 2.50	0.08 ± 0.00	2.09 ± 0.31	0.255 ± 0.014	0.46 ± 0.02
21	JoGokBeok	283.77 ± 17.23	2.33 ± 1.41	4.31 ± 0.02	1.61 ± 0.08	0.043 ± 0.010	0.10 ± 0.02
22	HyangOnGok-1	353.82 ± 35.81	0.69 ± 0.03	2.05 ± 0.19	1.58 ± 0.09	0.041 ± 0.009	0.04 ± 0.03
23	HyangOnGok-2	408.60 ± 42.88	0.78 ± 0.07	3.44 ± 0.56	1.62 ± 0.02	0.036 ± 0.004	0.03 ± 0.02
24	BakSuHwanDongJuGok	512.81 ± 6.26	28.09 ± 0.80	0.38 ± 0.07	2.64 ± 0.26	0.070 ± 0.011	1.07 ± 0.07
25	Nebubijeongok	565.20 ± 3.54	33.20 ± 2.24	4.11 ± 0.16	1.76 ± 0.29	0.050 ± 0.011	0.24 ± 0.03
26	NokMiJuGok	217.74 ± 24.29	21.17 ± 4.13	0.40 ± 0.05	3.33 ± 0.90	0.083 ± 0.032	1.09 ± 0.07
27	NokDuGok	210.59 ± 7.15	2.27 ± 1.01	0.10 ± 0.01	1.78 ± 0.12	0.032 ± 0.003	0.17 ± 0.02
28	Gok-2	334.91 ± 21.23	16.42 ± 8.45	4.17 ± 0.26	2.75 ± 0.97	0.043 ± 0.005	0.34 ± 0.30
29	MiGok-1	547.90 ± 18.10	22.18 ± 6.78	4.77 ± 0.36	2.11 ± 0.33	0.041 ± 0.004	0.21 ± 0.07
30	MyunGok-2	265.45 ± 46.99	4.54 ± 0.73	3.78 ± 0.92	1.98 ± 0.20	0.053 ± 0.006	0.18 ± 0.04
31	Gok-3	190.28 ± 7.11	2.32 ± 2.10	4.27 ± 0.15	1.62 ± 0.12	0.042 ± 0.012	0.10 ± 0.07
32	YoGok	143.42 ± 10.75	1.33 ± 0.26	0.07 ± 0.02	1.59 ± 0.12	0.173 ± 0.085	0.04 ± 0.05
33	DaeJuBackTaGok	189.51 ± 0.59	3.62 ± 1.06	2.38 ± 0.07	1.66 ± 0.20	0.077 ± 0.008	0.14 ± 0.07
34	BackRyoGok	244.06 ± 2.56	4.23 ± 0.65	1.12 ± 0.07	1.70 ± 0.15	0.083 ± 0.021	0.07 ± 0.01
35	YangNeungGok	183.92 ± 35.08	0.71 ± 0.09	1.71 ± 0.07	1.64 ± 0.03	0.037 ± 0.004	0.01 ± 0.01
36	BackJuGok-1	214.55 ± 57.45	1.10 ± 0.07	0.04 ± 0.02	1.71 ± 0.27	0.282 ± 0.013	0.04 ± 0.01
37	BackJuGok-2	222.16 ± 20.73	2.69 ± 0.38	0.05 ± 0.02	1.43 ± 0.15	0.046 ± 0.005	0.27 ± 0.05
38	ManJeonHangJuGok	267.99 ± 22.97	0.74 ± 0.03	2.84 ± 0.19	1.65 ± 0.04	0.037 ± 0.003	0.02 ± 0.02
39	JeongHwaGok	324.33 ± 5.46	43.41 ± 8.91	4.64 ± 0.62	2.16 ± 0.94	0.055 ± 0.003	0.47 ± 0.02
40	YeonHwaGok-2	516.06 ± 5.50	63.37 ± 5.13	0.68 ± 0.01	2.12 ± 0.15	0.046 ± 0.003	0.30 ± 0.02
41	DongYangJuGok	207.22 ± 87.05	23.14 ± 3.29	5.28 ± 0.36	2.11 ± 0.22	0.092 ± 0.006	0.21 ± 0.07
42	MiGok-2	101.99 ± 12.02	1.03 ± 0.12	0.05 ± 0.02	1.72 ± 0.06	0.043 ± 0.007	0.03 ± 0.01

Table 2. Continued.

No.	Nuruk	Saccharification power	Enzyme activity[a]				
			α-Amylase (U/g Nuruk)	β-Amylase (U/g Nuruk)	Protease (μg/ml trypsin)	β-Glucanase (U/g Nuruk)	Glucoamylase (U/g Nuruk)
43	ShinGok-1	356.61 ± 7.28	2.52 ± 0.63	0.30 ± 0.02	1.69 ± 0.33	0.038 ± 0.005	1.94 ± 0.17
44	ShinGok-2	340.37 ± 36.95	29.52 ± 4.28	4.14 ± 0.70	1.86 ± 0.20	0.174 ± 0.011	0.56 ± 0.12
45	ShinGok-3	215.02 ± 26.57	12.69 ± 0.80	1.79 ± 0.13	1.78 ± 0.22	0.050 ± 0.003	0.48 ± 0.09
46	HaDongShinGok	268.30 ± 8.59	4.29 ± 0.17	1.00 ± 0.06	1.88 ± 0.26	0.163 ± 0.013	0.07 ± 0.01
47	Commercial-1	423.59 ± 8.64	26.02 ± 5.22	4.23 ± 0.26	2.79 ± 1.58	0.150 ± 0.005	0.42 ± 0.08
48	Commercial-2	460.12 ± 18.81	30.33 ± 8.43	5.01 ± 0.47	5.04 ± 1.52	0.186 ± 0.025	0.53 ± 0.06
49	Commercial-3	356.56 ± 40.15	38.23 ± 17.56	5.18 ± 0.52	3.23 ± 2.60	0.133 ± 0.025	0.58 ± 0.33
50	Commercial-4	220.99 ± 23.81	21.98 ± 6.05	3.10 ± 0.20	1.70 ± 0.08	0.116 ± 0.012	0.75 ± 0.12
51	Commercial-5	418.80 ± 15.53	3.54 ± 0.65	0.90 ± 0.79	1.74 ± 0.11	0.047 ± 0.006	0.16 ± 0.06
52	Commercial-6	346.28 ± 57.71	3.46 ± 1.40	0.11 ± 0.03	1.72 ± 0.14	0.042 ± 0.006	0.13 ± 0.06
53	Commercial-7	229.63 ± 14.59	8.01 ± 1.27	1.98 ± 0.06	1.72 ± 0.09	0.083 ± 0.002	0.27 ± 0.02
54	Self-produced-1	255.12 ± 24.15	8.77 ± 3.51	1.45 ± 0.32	1.88 ± 0.73	0.212 ± 0.125	0.35 ± 0.18
55	Self-produced-2	268.78 ± 37.49	12.00 ± 3.67	3.48 ± 0.30	1.78 ± 0.09	0.039 ± 0.006	0.52 ± 0.17
56	Self-produced-3	250.13 ± 26.04	3.87 ± 0.24	1.15 ± 0.14	1.74 ± 0.03	0.155 ± 0.003	0.15 ± 0.01
57	Self-produced-4	402.10 ± 38.38	55.49 ± 27.03	2.97 ± 0.16	10.32 ± 0.36	0.239 ± 0.045	1.52 ± 0.20
58	Self-produced-5	175.49 ± 16.92	6.61 ± 0.26	2.44 ± 0.16	1.69 ± 0.46	0.175 ± 0.031	0.25 ± 0.10

[a]Means ± SD (n = 3).

Table 3. Brewing properties of Korean traditional nuruks.

No.	Nuruk	Saccharification power	Addition (%)	Alcohol (%)	RS (mg/ml)	Total acidity (%)	pH
1	JuKokBangMun	325.4	20%	12.87	19.0	0.78	4.0
2	ChuMoGok	194.8	20%	17.60	<2	0.43	4.2
3	OMeKiGok	151.4	10%	18.16	5.3	0.37	4.0
4	JukGok-1	319.3	20%	16.96	<2	0.45	4.1
5	JukGok-2	265.9	20%	16.95	9.3	0.50	4.1
6	KongByungGok	318.8	10%	16.09	<2	0.39	4.1
7	Gok-1	346.7	20%	13.44	13.0	0.71	4.1
8	MyunGok-1	292.2	10%	16.45	8.0	0.32	3.9
9	SinGok-1	137.5	10%	12.62	9.8	0.78	3.6
10	JinjuchunchuGok	163.5	10%	16.49	12.6	0.39	4.0
11	YeoGok-1	85.5	10%	15.78	8.4	0.37	3.8
12	SeolhangGok	211.5	20%	9.95	8.5	0.91	3.6
13	YeonHwaGok-1	112.7	20%	17.01	5.8	0.63	3.9
14	BackGok-1	150.8	20%	11.24	14.1	1.02	3.7
15	BackGok-1	164.6	10%	14.59	12.2	0.41	4.2
16	YeoGok-2	370.1	20%	12.52	12.9	0.68	3.8
17	BunGok	565.5	20%	17.24	<2	0.64	4.1
18	ByungGok	395.2	10%	15.34	<2	0.36	4.3
19	IWhaJuGok	241.1	20%	18.20	7.6	0.41	4.3
20	IWhaGok	351.3	20%	17.68	<2	0.42	4.1
21	JoGokBeok	283.8	20%	16.09	19.8	0.40	4.2

Table 3. Continued.

No.	Nuruk	Saccharification power	Addition (%)	Alcohol (%)	RS (mg/ml)	Total acidity (%)	pH
22	HyangOnGok-1	358.8	-	-	-	-	-
23	HyangOnGok-2	408.6	20%	13.32	40.6	0.35	4.0
24	BakSuHwan-DongJuGok	512.8	10%	15.47	<2	0.35	3.9
25	Nebubijeongok	565.2	10%	14.68	17.3	0.34	3.8
26	NokMiJuGok	217.7	20%	17.08	<2	0.44	4.4
27	NokDuGok	210.6	-	-	-	-	-
28	Gok-2	334.9	20%	15.22	15.6	0.49	4.2
29	MiGok-1	547.9	20%	17.33	<2	0.37	4.3
30	MyunGok-2	265.5	10%	10.95	25.6	0.45	3.9
31	Gok-3	190.3	20%	14.86	8.3	0.51	4.3
32	YoGok	143.4	20%	17.56	8.5	0.37	4.1
33	DaeJuBackTaGok	189.5	10%	12.67	22.0	0.43	3.8
34	BackRyoGok	244.1	10%	14.74	17.3	0.32	4.0
35	YangNeungGok	183.9	20%	15.22	6.9	0.35	4.2
36	BackJuGok-1	214.5	20%	11.68	5.3	0.74	3.8
37	BackJuGok-2	222.2	20%	14.88	<2	0.59	4.0
38	ManJeonHangJuGok	268.0	20%	11.33	14.5	0.56	3.8
39	JeongHwaGok	324.3	10%	15.68	9.7	0.38	3.9
40	YeonHwaGok-2	516.1	20%	17.31	8.1	0.40	4.4
41	DongYangJuGok	207.2	10%	14.44	7.0	0.31	4.4
42	MiGok-2	102.0	-	-	-	-	-
43	ShinGok-1	356.6	20%	14.02	3.3	1.06	3.8
44	ShinGok-2	340.4	10%	15.55	10.3	0.32	4.3
45	ShinGok-3	215.0	10%	14.23	8.5	0.86	3.5
46	HaDongShinGok	268.3	20%	13.21	10.0	0.96	3.9
47	Commercial-1	423.6	10%	16.93	10.4	0.31	4.3
48	Commercial-2	460.1	10%	15.63	22.1	0.29	4.3
49	Commercial-3	356.6	10%	16.33	11.9	0.34	4.3
50	Commercial-4	221.0	20%	17.20	5.0	0.43	4.2
51	Commercial-5	418.8	20%	14.10	14.0	0.33	4.2
52	Commercial-6	346.3	20%	9.03	25.1	1.03	3.8
53	Commercial-7	229.6	10%	13.14	13.7	0.32	3.7
54	Self-produced-1	255.1	10%	16.17	4.7	0.41	4.1
55	Self-produced-2	268.8	10%	13.28	10.3	0.46	3.7
56	Self-produced-3	250.1	10%	15.25	<2	0.34	3.9
57	Self-produced-4	402.1	10%	18.82	<2	0.43	4.3
58	Self-produced-5	175.5	10%	15.99	7.6	0.33	4.2

ingredient had a sweet and sour taste, and showed soft and richly flavored organoleptic characteristics. There were noticeable differences in intensity of bitterness, astringent taste, and body depending on the characteristics of the nuruk used in production. Flour seemed to contribute increasingly to the unique savory flavor of the traditional Korean alcoholic beverages and showed brewing characteristics such as smooth taste, weak, bitter, and astringent tastes, and simple and rich flavors. In particular, if mung beans were used as a supplementary material in the production

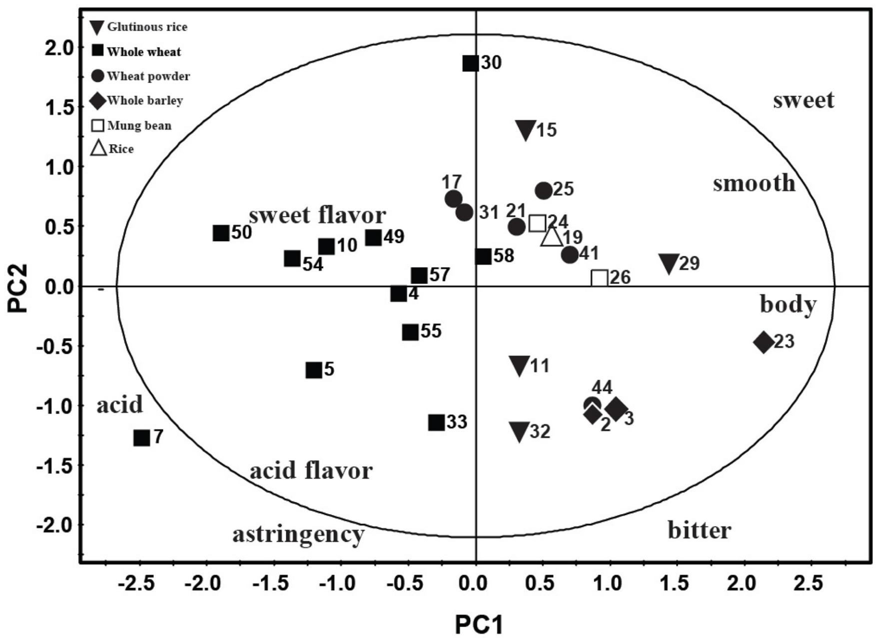

Fig. 2. Principle component analysis on characteristics of alcoholic beverages prepared with restored traditional nuruks.

of nuruk, the resulting beverage had a fruity flavor similar to fruit wine in the final product, which is a desirable sensory characteristic in traditional alcoholic beverages. Nuruk produced using whole barley as the main ingredient had a weak sweet taste, but also had a full body because of a blend of sour, bitter, and astringent tastes. Nuruk produced using whole barley featured a unique body of grains similar to beer, and was not strongly sweet, but had a unique flavor characteristic of grain and was also rich in bitter sweet flavor. Nuruk produced using rice and glutinous rice had a strong sweet taste and stable fermentation, producing moderate alcohol and a bitter and astringent taste that remained slightly after fermentation. Beverages produced using mung beans have a palatable blend of sweet and sour taste, with characteristics of a soft, light bodied, low-astringent, and bitter taste and especially good rich fruity flavor and full body. Taking the sensory characteristics of each raw material together, nuruk with wheat (whole wheat, flour, and wheat bran) as the main ingredient generally led to stable fermentation, and produced alcoholic beverages with a rich flavor, and a variety of flavors when compared with other main raw materials. Beverages produced using whole barley nuruk had a unique flavor and were rather rough. Conversely, nuruk prepared from rice or glutinous rice as the main ingredient had full-bodied character that tended to have a smoother taste and flavor than those produced using other nuruks. Traditional Korean alcoholic beverages produced by nuruks in which mung beans were distinctively used as the main raw material (no. 24 BacksuHwandongJugok, 26 NokmiJugok) and supplementary materials (No. 21 JugokBeop, 23 HyangonGok, 30 Myeongok, 31 Gok, 25 NaeBunbuBijeongok) had strong fruity flavors and were typically characterized as fruit wines owing to a combination of their sweet and sour tastes. Meanwhile, the analytical results of the sensory characteristics according to the types of supplementary materials used in the nuruk showed that traditional alcoholic beverages produced by nuruks containing mung beans and its juice had strong characteristics of fruity and floral flavors, and a high organoleptic preference. In addition, nuruk-based traditional Korean alcoholic beverages brewed with smartweed juice were found to have savory and sweet tastes and were smoothly blended. On the other hand, it is notable that traditional Korean alcoholic beverages produced using nuruk in which pharmaceutical plants were mixed had a slower fermentation rate and lower alcohol production rate. These typically had the characteristics of a strong taste and flavor due to the bitterness and harshness of the ingredients derived from the medicinal herbs or pharmaceutical plants.

In conclusion, in the present study, we have demonstrated that the sensory characteristics of traditional Korean alcoholic beverages are determined in part by the types of raw and supplementary materials used in the nuruk. Each raw and supplementary material used in producing the nuruk had its own unique brewing and organoleptic characteristics on traditional Korean alcoholic beverage fermentation. Additional investigations on the relationship among the microbial communities, changes in the metabolite composition, and brewing characteristics are necessary to produce high-quality traditional alcoholic beverages.

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