Concept of Nuruk on Brewing Technology

Jang-Eun Lee and Jae-Ho Kim

Abstract

Nuruk is a traditional Korean fermentation starter that is used to produce starch-based alcoholic beverages using various cereals as raw material. As a determinant factor for flavor, taste, and color of alcoholic beverages, Nuruk is an indispensable ingredient for brewing alcoholic beverages in Korea. Nuruk shows significant variation in the shape, and in the brewing and fermentation methods, which are dependent on the unique climate in each area. Therefore, it is worthy to note that the characteristics of Korean traditional Nuruk are based on its diversity. Thus, this chapter is aimed to scientifically identify the characteristics of traditional Nuruk on brewing technology. In this chapter, the concept of Nuruk will be discussed in terms of its history, production, microorganism diversity, and enzymatic function.

Keywords: fungi, microorganisms, Nuruk, saccharification power, yeast

1. Introduction

Nuruk, a fermentation starter used for brewing alcoholic beverages from grains, is a dough made from grains, such as wheat, barley, or rice that are germinated by enzyme-releasing microorganisms. In Asian countries, starch is the main ingredient for alcohol fermentation, which is first hydrolyzed to glucose through the saccharification process by fungi. Nuruk, also called “Gokja” in Korea, contains naturally occurring and multiplying microorganisms such as wild fungi, yeast, and lactic acid bacteria. Traditionally, Nuruk has been made from several grains such as wheat, barley, rice, and millet etc., and grains are used as the main raw material for Nuruk and alcohol beverages processing.

In Korea, Nuruk shows significant variation in the shape, and in the brewing and fermentation methods, which are dependent on the unique climate in each area. It has been shown that Nuruk production can be adapted to suit the 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 depend on the geographical and climatic diversities of their production area. However, the use of traditional Nuruk, in a variety of traditional brewing method is dwindling due to the recent increase in the use of industrial commercial fermentation starter [1]. In Korea, research on traditional Nuruk was started in the early 1900s by the Japanese, but had not actively progressed until recently. Currently, research on the production of certain traditional Nuruk [2–4], Nuruk-derived microorganisms [5–9], traditional Nuruk-derived Korean alcoholic beverages [10–13], and their physiological functions [14–17] are being performed. In addition, investigation on the Nuruk microbial communities [18–20] as well as the metabolite analysis of Nuruk [20] was recently performed.

In this chapter, the use of Nuruk in brewing technology will be discussed in terms of its history, production, microorganism diversity, and enzyme function.

2. History of Nuruk

Nuruk was first made in Asia in the fifth century BC. It is believed that Nuruk was first used in Korea before the “three kingdoms period,” and records show Nuruk being used for Korean alcohol production in the 1123 CE book Goryeo Dogyeong (Chi.: Gaolitujing) by Xu Jing. Hallimbyeolgok from the Goryeo period mentions an alcohol brewed with a special type of Nuruk, indicating the existence of several types of Nuruk in Korea at that time. Gyugonsiuibang (1670), a classic text about food in the mid-Joseon period, records the names and detailed manufacturing methods for different types of Nuruk, highlighting that a diverse range of traditional Nuruks were manufactured during that period. In classic texts, Nuruk was called Guk, and after 1918, it was called Gokja; however, currently the term “Nuruk” is more common than Gokja.

During the reign of the Joseon dynasty, Nuruk was classified into two categories: the ddeok-Nuruk was made of a lump of grain powder and the Heuchim-Nuruk was made of cereal grains. The appearances of ddeok-and Heuchim-Nuruk are presented in Figure 1. The ddeok-Nuruk contained a variety of microorganisms such as fungi, lactic acid bacteria, and yeasts deep inside the lump, which imparted rich and complex flavor to alcohol. In contrast, fungi germinating only on the surface of the heuchim-Nuruk, provided simple and light tastes.

The dry climate of China favored the development of the shaped Nuruk from wheat, whereas the humidity of the Japanese climate promoted the development of dispersed Nuruk from rice. Meanwhile, Korea developed both the types of Nuruk. Thus, Nuruks differ in particle shape, manufacturing methods, and fermentation time, depending on the unique climate and environment of the manufacturing country, thereby exemplifying the adaptation ability of
Nuruk to climatic and geographical conditions. In contrast to the shaped and dispersed Nuruk developed by China and Japan, respectively, Korea developed Nuruk with diverse ingredients and appearances. For example, Nuruk grain particles of mountainous regions tend to be broad and flat, whereas Nuruk particles of the plains are thick and small, and those in the Jeju region are small and flat. These regional differences occur due to variations in the content of the main ingredients and the environment, such as the levels of humidity and sunlight. Several kinds of representative traditional Korean Nuruk are displayed in Figure 2. As shown in Figure 2, this diversity is the characteristic of the traditional Korean Nuruk, which has been promoted by the development of a unique and varied traditional home brewing culture.

Figure 1. Dispersed heuchim-Nuruk (A) and shaped ddeok-Nuruk (B and C).

Figure 2. Appearance of various traditional Korean Nuruk [21].
3. Nuruk production

To ferment Nuruk, fungi or bacteria are germinated on a culture medium which is made of starchy grains such as rice, wheat, and barley. Wheat and barley are the most popular materials for Nuruk fermentation as they impart quality taste and flavor to Nuruk.

The Nuruk manufacture method is summarized in Figure 3. Traditionally, ground wheat is mixed with water, put in a mold, and pressed into the desired shape (Figure 4). Whole grains are thoroughly ground and finely sifted, mixed with other supplemental materials, and pressed into a frame to shape Nuruk. The shaped Nuruk is germinated with microorganisms for 2–3 days buried under supplementary materials such as straw or wormwood at a temperature of 30–35°C. The growth of yellowish fungi in the center of the pressed mass indicates that the Nuruk should be dried under the sun, thoroughly crushed, and finely sifted. Favorable temperature and humidity are critical to the culture of fungi on Nuruk. Nuruk can be globe-shaped, flat round disk-shaped, or rectangular with a hole in the center. Nuruk must be made in just the right size and thickness. Small and thin Nuruk loses moisture easily, which causes incomplete germination of fungi and defective fermentation, resulting in undesirable flavor, and low alcohol yield. In contrast, a thick Nuruk limits moisture loss and increases the temperature inside the fermentation jar. A well-cultured Nuruk is critical for the clear color and fresh flavor of fermented grain.

![Figure 3. Nuruk production.](image)

![Figure 4. Nuruk is put in a mold and pressed into the desired shape. (A) traditional molding method, (B) mechanization for mass produce Nuruks.](image)
4. Microorganisms in Nuruk

Various types of microbes exist in Nuruk because of the coexistence of raw material (raw starch)-derived microorganisms and environment-derived microorganisms that were acquired during the fermentation. Since Nuruk mainly consists of starch, microorganisms that are capable of degrading beta-starch are predominant in Nuruk. Specifically, various types of yeast, lactic acid bacteria, and aerobic bacteria that cause alcoholic fermentation are present in Nuruk. Some kinds of Nuruk derived microorganisms that were found by Kim et al. [14] are shown in Figure 5.

In general, the fungus that grows in yeast has high starch decomposition activity, and thus hydrolysis of starch during alcoholic fermentation produces fermentable saccharides. In addition, fungi also produce alcohol from fermentable sugars. Lactic acid bacteria are involved in maintaining the acidity of the fermentation environment, which enables progression of alcoholic fermentation by acid-producing fungi. Mold, a group of mesophilic fungi that grows well at 25–30°C and in weakly acidic conditions, plays an important role in brewing because it secretes glycosylation enzymes required for hydrolyzing starch into fermentable saccharides. Therefore, fermentative molds in low pH environment exhibit high liquefaction and glycation.

![Figure 5](image-url)
abilities. The most common molds found in Nuruk are *Absidia* sp, *Aspergillus oryzae*, *Rhizopus* sp., *Penicillium* sp., and *Mucor* sp., which secrete various amylases such as α-amylase and glucoamylase that act on stored starch of cereals. The molds most frequently isolated from Nuruk are *R. oryzae* and *A. oryzae*. In Asia, these two strains are important fungi in the food industry because they are used in the manufacture of traditional fermented foods. *R. oryzae* is a pathogenic fungus that causes zygomycosis [22] and is a pioneer saprotroph that initially infects dead plants and rapidly penetrates inside degradable substrates. Recent genomic studies showed that *R. oryzae* does not contain the genes necessary for exo-cellulose degradation and is an auxotroph for degradation of pectin, xyloglucan, xylan, and inulin. Thus, the ability to degrade simple polysaccharides, such as monosaccharides and starches, underscores the dominance of *R. oryzae* over other fungi [23].

Among yeasts, *R. oryzae* acts as a primary colonizer in the early stages of fermentation and participates in the decomposition of yeast constituents. However, as the internal temperature of the mold increases with progression of fermentation, the temperature-sensitive *R. oryzae* gradually falls out of competition with the high temperature-resistant fungi such as *A. oryzae* [24]. *A. oryzae* possesses high glycation ability and secretes α-amylase [25], and is therefore important for glycosylation and liquefaction [8, 24]. However, it is difficult to distinguish *A. oryzae* from aflatoxin-producing *A. flavus* using conventional taxonomic criteria because of its close relationship with *A. flavus*; thus, *A. oryzae* should be tested for its ability to produce aflatoxin [26, 27].

The members of the aflatoxin biosynthetic pathway are encoded by a cluster of 25 genes [28], the expression levels of which are primarily regulated by aflR, a transcriptional activator [29]. Therefore, polymorphism, deletion, and the presence of aflR binding sites have been used as important indicators to determine aflatoxin biosynthesis [26]. Particularly, the aflR binding sites of *norB* and *cypA* are critical for the expression of the entire aflatoxin biosynthesis-associated gene group. In general, *A. oryzae* and *A. flavus* are divided into type I deletion (0.3 kb) and type II deletion (0.8 kb) groups based on the partial deletion pattern of *norB-cypA* (1.8 kb), and it was found that the type I deletion group does not produce aflatoxin [27, 30, 31].

### 5. Enzymatic activity 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. Enzymatic activity of Nuruk can mainly be estimated by the index of saccharification power (sp). This saccharification power represents the index of how much soluble starch can be enzymatically converted to simpler sugars by diastatic enzymes in Nuruk. Previous studies on the enzymatic activity of early Nuruk showed that the saccharification power (sp) of Korean 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) [32]. According to previous study [33], it has been reported that the saccharification power of Backguk produced by *Aspergillus kawachii* and Hwangguk produced by *Asp. oryzae* were being used in all areas 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).
| No. | Nuruk          | Saccharification Power | 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          | 1.58 ± 0.36          | 3.82 ± 0.17               | 0.048 ± 0.008            | 0.16 ± 0.10              |
| 2   | ChuMoGok       | 174.82 ± 20.10         | 17.42 ± 1.10         | 1.44 ± 0.76          | 1.77 ± 0.41               | 0.041 ± 0.004            | 0.191 ± 0.020            |
| 3   | OMeKiGok       | 194.24 ± 11.11         | 8.72 ± 1.98          | 1.42 ± 0.57          | 1.42 ± 0.57               | 0.108 ± 0.014            | 0.57 ± 0.05               |
| 4   | Gok-1          | 151.44 ± 16.11         | 39.07 ± 6.70         | 3.83 ± 0.24          | 4.77 ± 0.21               | 0.09 ± 0.004             | 0.046 ± 0.016            |
| 5   | KongByungGok   | 265.93 ± 15.80         | 10.75 ± 1.81         | 1.42 ± 0.57          | 1.75 ± 0.22               | 0.087 ± 0.008            | 0.16 ± 0.05              |
| 6   | ChuMoGok-1     | 174.82 ± 20.10         | 17.42 ± 1.10         | 1.44 ± 0.76          | 1.77 ± 0.41               | 0.041 ± 0.004            | 0.191 ± 0.020            |
| 7   | MyoMok-1       | 163.53 ± 0.09          | 16.61 ± 2.85         | 0.05 ± 0.001         | 1.76 ± 0.31               | 0.091 ± 0.007            | 0.31 ± 0.06              |
| 8   | SeoMok-1       | 185.50 ± 6.12          | 9.45 ± 6.73          | 1.63 ± 0.07          | 1.58 ± 0.07               | 0.161 ± 0.052            | 0.29 ± 0.08              |
| 9   | Gok-1          | 151.44 ± 16.11         | 39.07 ± 6.70         | 3.83 ± 0.24          | 4.77 ± 0.21               | 0.087 ± 0.008            | 0.16 ± 0.05              |
| 10  | JinMok-1       | 174.82 ± 20.10         | 17.42 ± 1.10         | 1.42 ± 0.57          | 1.75 ± 0.22               | 0.087 ± 0.008            | 0.16 ± 0.05              |
| 11  | SeoMok-1       | 185.50 ± 6.12          | 9.45 ± 6.73          | 1.63 ± 0.07          | 1.58 ± 0.07               | 0.161 ± 0.052            | 0.29 ± 0.08              |
| 12  | Gok-1          | 151.44 ± 16.11         | 39.07 ± 6.70         | 3.83 ± 0.24          | 4.77 ± 0.21               | 0.087 ± 0.008            | 0.16 ± 0.05              |
| 13  | Gok-1          | 151.44 ± 16.11         | 39.07 ± 6.70         | 3.83 ± 0.24          | 4.77 ± 0.21               | 0.087 ± 0.008            | 0.16 ± 0.05              |
| 14  | Gok-1          | 151.44 ± 16.11         | 39.07 ± 6.70         | 3.83 ± 0.24          | 4.77 ± 0.21               | 0.087 ± 0.008            | 0.16 ± 0.05              |
| 15  | Gok-1          | 151.44 ± 16.11         | 39.07 ± 6.70         | 3.83 ± 0.24          | 4.77 ± 0.21               | 0.087 ± 0.008            | 0.16 ± 0.05              |
| 16  | Gok-1          | 151.44 ± 16.11         | 39.07 ± 6.70         | 3.83 ± 0.24          | 4.77 ± 0.21               | 0.087 ± 0.008            | 0.16 ± 0.05              |
| 17  | Gok-1          | 151.44 ± 16.11         | 39.07 ± 6.70         | 3.83 ± 0.24          | 4.77 ± 0.21               | 0.087 ± 0.008            | 0.16 ± 0.05              |
| 18  | Gok-1          | 151.44 ± 16.11         | 39.07 ± 6.70         | 3.83 ± 0.24          | 4.77 ± 0.21               | 0.087 ± 0.008            | 0.16 ± 0.05              |
| 19  | Gok-1          | 151.44 ± 16.11         | 39.07 ± 6.70         | 3.83 ± 0.24          | 4.77 ± 0.21               | 0.087 ± 0.008            | 0.16 ± 0.05              |
| 20  | Gok-1          | 151.44 ± 16.11         | 39.07 ± 6.70         | 3.83 ± 0.24          | 4.77 ± 0.21               | 0.087 ± 0.008            | 0.16 ± 0.05              |
| 21  | Gok-1          | 151.44 ± 16.11         | 39.07 ± 6.70         | 3.83 ± 0.24          | 4.77 ± 0.21               | 0.087 ± 0.008            | 0.16 ± 0.05              |
| No. | Nuruk                  | Saccharification power | Enzyme activitya |  
|-----|------------------------|------------------------|------------------|  
|     |                        |                        | α-Amylase (U/g Nuruk) | β-Amylase (U/g Nuruk) | Protease (μg/ml trypsin) | β-Glucanase (U/g Nuruk) | Glucoamylase (U/g Nuruk) |
| 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  | NokMjuGok              | 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               |
| No. | Nuruk            | Saccharification Power | Enzyme activity<sup>a</sup> | 
|-----|------------------|------------------------|------------------------------|
|     |                  |                        | 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         | 8.46 ± 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                  |

<sup>a</sup> Means ± SD (n = 3).

Table 1. Saccharification power and enzyme activities of Korean traditional Nuruk [21].
In Lee et al.’s study [21], 58 different kinds of traditional Nuruk were prepared, including 46 types of restored Nuruk mentioned in ancient documents. The saccharification power and glucoamylase, α-amylase, β-amylase, protease, and β-glucanase activities of each Nuruk were reported. Among the 46 different kinds of restored and 12 types of collected Nuruk, the saccharification power values were the highest in Bungok (791 sp), followed by Gokja (421 sp), Hwangguk (226 sp), and Backguk (195 sp). The saccharification power of 12 kinds of commercial and self-produced Nuruk and their measured enzymatic activities have been reported through Lee’s study [21] that can be shown in Table 1. The range of saccharification power of the restored Nuruk was 85–565 sp. Nuruk with the highest saccharification power was shown in Bungok (565.5 sp), Naebubijeon (565.2 sp), and Migok (547.9 sp). This indicate that some restored Nuruk has 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 was higher than JinjuGokja (26–38 U/g) showing a high activity among collected Nuruk. Bungok had higher α-amylase activity than self-manufactured Nuruk, Igasubul (55.49 U/g). Also, the β-amylase activity was the highest in Jinjugokja which is commercially available, and protease activity was highest in the self-manufactured Igasubul (10.32 μg/mL), followed by restored Omegigok (9.9 μg/mL). The α-amylase and β-amylase activities correlated significantly with the 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 were not correlated with saccharification power value.

Author details

Jang-Eun Lee* and Jae-Ho Kim

*Address all correspondence to: jelee@kfri.re.kr

Traditional Alcoholic Beverages Research Team, Korea Food Research Institute, Gyeonggi-do, Republic of Korea

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