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Comparison of Dietary Fiber and Free Sugar Content Between Raw and Cooked Cereal Grains

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ABSTRACT - Cereal grains are the dietary staple in many countries, including the Republic of Korea. These grains are usually consumed cooked. Korean grown raw and cooked brown non-glutinous rice (BNR), white non-glutinous rice (WNR), oats, and barley were analyzed to assess the effects of cooking on dietary fiber and free sugar content. The largest decrease in total dietary fiber (TDF) after cooking was observed in barley (11.62±1.26 to 2.96± 0.90 g/100 g), and the smallest decrease was observed in oats (8.1±0.34 to 8.1±0.32 g/100 g). Soluble dietary fiber decreased in oats (3.35±0.94 to 1.25±0.03 g/100 g) while insoluble dietary fiber increased (4.76±0.78 to 6.90±0.30 g/100 g) after cooking. TDF content was not changed. Of the six free sugars routinely assessed, only sucrose was detected in BNR and WNR. Sucrose decreased by about 0.6 g/100 g in BNR, and was not detected in WNR, after cooking. Fructose, sucrose, and raffinose were detected in oats (0.08, 0.83, and 0.19 g/100 g) and barley (0.09, 0.58, and 0.22 g/100 g) Maltose was also detected in barley (0.09 g/100 g). Total sugar content decreased in every cereal grain sample after cooking. This research reveals that dietary fiber and free sugar content can be reduced by cooking cereal grains.

Key words: Cereal grains, Dietary fiber, Free sugar, Analysis, HPLC

Cereal grains are a part of a plant, made up of the endosperm, germ, and bran. Grains such as rice, barley, and oats are eaten as staple foods in many countries, reaching almost half of the calorie intake around the world[1]. According to the USDA, about 2.7 billion tons of grains were consumed worldwide in 2020[2]. They provide carbohydrates, proteins, and lipids that are beneficial to humans and are a source of dietary fibers[3]. As the interest in consuming a healthy diet has been constantly increasing, the demand for multigrain rice such as brown rice, barley, oat, and bean is increasing[4]. Also, as the health values of whole grains are known, more people tend to eat whole grains or mixed grains.

Mixed grains are known to have more than two times of nutrients such as dietary fiber, proteins, and minerals compared to white rice[4]. Usually, barley and oat showed high total dietary fiber (TDF) content among other grains[5]. Brown rice is also a good source of dietary fiber, but when brown rice is milled to become white rice, fiber decreases because the bran contains most of the dietary fiber[6]. Dietary fiber is defined as the edible parts of the plant that are indigestible, by the American Association of Cereal Chemists (AACC). Studies have shown various health benefits such as improvement of intestinal health, reduces cardiovascular disease, and reduces insulin synthesis when consuming cereal grains rich in dietary fiber[7,8]. Dietary fiber consists of soluble dietary fiber (SDF), which dissolves in water, and insoluble dietary fiber (IDF). SDF is known to be helpful in lowering glucose absorption speed, and IDF is known to improve intestinal health[9]. The recommended dietary fiber intake is 20-35 g, and cereal grains provide about 50% of the required amount[10]. The dietary fiber content was analyzed by the enzymatic method developed by Prosky et al.[11].

Aside from dietary fiber, cereal grains are mostly composed of carbohydrates which is the main source of energy when consumed. Carbohydrates can be divided into three groups, oligosaccharides, monosaccharides, and polysaccharides. Sucrose, maltose, and lactose belong to monosaccharides, and glucose, galactose, and fructose belong to polysaccharides[12]. Starch, which is abundant in grains, is usually in the form of sucrose, which is then degraded to fructose and glucose[13].

Cereal grains are usually consumed in various forms like

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bread, noodles, powder, and dried, but most as simply cooked form[14]. It is cooked by the mixture of boiling, then steaming method, or simply using a rice cooker. During these steps, the chemical composition and physical structure of grains changed, including starch contents[15,16].

Several studies about the content of dietary fiber or free sugar in raw cereal grains has been conducted. Comparison of TDF between different cultivars of cereal grains such as rice[17] and barley[18] were also studied.

Recent studies show the changes of dietary fiber when grains are cooked. Rice showed changes of nutritional quality including dietary fiber content by two types of cooking, pressure cooking and microwave cooking[17]. Change of dietary fiber in barley by different heating methods such as boiling, pressure-cooking, and roasting were studied by Ain et al.[19]. In oats, the change of TDF, IDF and SDF were compared according to the different thermal processing methods such as frying, high pressure steaming, normal pressure steaming, and high pressure steaming[20].

Free sugar content in several cereal grains including raw white rice[21], raw brown rice[22], raw barley[23], raw oat flour[24] was studied, and the changes of glycemic index after intake of cereal grains were observed. However, there was a lack of research about the change of TDF, IDF and SDF after cooking of different kinds of cereal grains altogether. Also, there were studies about the analysis of the total carbohydrate content in cereal grains, but not much results about the change of free sugar content such as content of fructose, galactose, lactose was found.

This study was conducted to evaluate the changes in IDF, SDF, TDF, and free sugar contents after cooking oat, white non-glutinous rice, brown non-glutinous rice, and barley to provide information for consumers.

Materials and Methods

Sample preparation

Four non-glutinous white and brown rice varieties, which are Samkwang (Gyeonggi), Saeilmi (Gyeongnam), Shindongjin (Jeonbuk), and Odae (Gyeonggi), four varieties of barley (Nurichal, Hogang, Keunalbori no. 1, and Heuksujeongchal) harvested in Jeonbuk, and two oat varieties (Daeyang and Joyang) harvested in Jeonbuk were procured from the Agricultural Science and Technology Institute of the Rural Development Administration (Wanju, Korea). For cooking of grains, WNR was soaked for 1 h in water 1.5 times the weight of WNR, then was cooked for 30 mins using a pressure cooker (CUCKOO CRP-K1060SR, Cuckoo, Yangsan, Korea). BNR, oat and barley were for 3 h in water 1.5 times the weight of each grain and cooked for 30 mins using a pressure cooker (CUCKOO CRP-K1060SR, Cuckoo, Yangsan, Korea). The grain samples arrived in a freeze-dried and grounded form.

Analysis of dietary fiber

The dietary fiber content of grain samples was analyzed using the AOAC Prosky method[11]. Each sample (1 g) was weighed in tall beakers. 40 mL of pH 8.2 MES-TRIS buffer and 50 μL of α-amylase (Sigma-Aldrich, St. Louis, MO, USA) were added to each sample and stirred. The samples were incubated in a 100°C hot water bath for 15 min, then cooled at room temperature. 10 mL of distilled water and 100 μL of protease (Sigma-Aldrich, St. Louis, MO, USA) were added, then incubated at 60°C for 30 min. 5 mL of 0.561 N HCl was added pH was adjusted to 4 using 6 N NaOH and 1 N HCl. After pH adjustment, 300 μL of amyloglucosidase (Sigma-Aldrich, St. Louis, MO, USA) was added and was incubated in a 60°C water bath for 30 min. Fritted crucible (PYREX®, Corning, NY, USA) containing 1 g of diatomaceous earth was prepared for filtration with the addition of 15 mL of distilled water while air suction was applied.

For analyzing IDF, the enzyme was filtered, and the filtrate was kept for analyzing SDF. The residue in the beaker was washed with 78% ethanol, 95% ethanol, then acetone while air suction was applied. For SDF, four volumes of 95% of the filtrate were added, incubated in the hot water bath for 1 h, then filtered through the crucibles and washed with 78% ethanol, 95% ethanol, then acetone. The residues in the beaker were washed with 78% ethanol, 95% ethanol, then acetone. All the crucibles were dried in a 105°C oven overnight, cooled down in a desiccator for 1 h, and weighed.

Standard sample preparation for free sugar analysis

The free sugar analysis of standard samples was conducted according to the qualitative and quantitative method of sugars by the apparatus analysis of carbohydrates in the Korean food code[12]. Standard samples were prepared by placing fructose, glucose, sucrose, lactose, maltose, and raffinose in a 60°C dry oven for 12 h. The standard solution was made by mixing 0.5 g of each standard with 50 mL HPLC grade water (Fisher Scientific, Seoul, Korea) to make a 1% solution and was diluted for use. Each standard sample was diluted to 7,000 ppm, 5,000 ppm, 2,500 ppm, 1,250 ppm, 625 ppm, and 312.5 ppm. The mobile phase was obtained by mixing HPLC grade water (Fisher Scientific, Seoul, Korea) and HPLC grade acetonitrile (Fisher Scientific, Seoul, Korea) up to 75%, filtered using a 0.22 μm filter (Pall Corporation, Ann Arbor, MI, USA) and mixed well by ultrasonication for 30 min. Each cereal grain sample (5 g) was placed in a 50 mL colonial tube and was mixed with 25 mL of 50% ethanol. The tube was weighed and incubated in an 85°C hot water bath for 25 min. After incubation, the samples were cooled and adjusted to the constant volume, 25 mL. Finally, the samples were filtered using a 0.45 μm syringe filter (Futecs, Daejeon, Korea) and kept in a glass vial.

Free sugar analysis using HPLC

The free sugar analysis of cereal grain samples was analyzed using the Korean food code[12]. Shimadzu LC-20AD HPLC system (Shimadzu, Kyoto, Japan) was used to perform HPLC. The samples were analyzed using a 4.6 mm I.D. × 250 mm Asahipak NH2P-50 4E carbohydrate column (Shodex, Tokyo, Japan) at 35°C. Acetonitrile (75%) was used as the mobile phase at the flow rate of 1.0 mL/min, and the injection volume was 10 μL, run for 30 min. 10 μL of 6 standard samples and food samples were used to establish the linearity. The concentration (mg/mL) of each sugar in the test solution was calculated using a calibration curve obtained by the peak area or height of the standard solution then the sugar content (g/100 g) was calculated using the equation below.

$$\text{Sugar content}\left(\frac{g}{100\ g}\right) = S \times \frac{a \times b}{\text{amount of sample (g)}} \times \frac{100}{1{,}000}$$

S: Concentration of sugars in the test solution; a: Total amount of the test solution; b: Dilution rate

Statistical analysis

The statistical analysis was performed using SPSS (Statistical Package for Social Sciences, SPSS Inc., Chicago, IL, USA). The means and standard deviations were calculated[25]. All experiments were performed in duplicate. A probability (P) level of 0.05 was considered statistically significant.

Results and Discussion

Dietary fiber contents of raw cereal grains

Soluble, insoluble, and total dietary fiber content of cooked and raw grains by each variety are arranged in Table 1. The SDF, IDF, and TDF ranged from 0.23-0.65 g/100 g, 2.79-4.50 g/100 g, and 3.02-5.14 g/100 g in BNR, N.D-0.41 g/100 g, 1.35-2.83 g/100 g, and 1.75-2.96 g/100 g in WNR, 3.80-6.17 g/100 g, 5.64-7.58 g/100 g and 9.53-12.82 g/100 g in barley, and 2.41-4.28 g/100 g, 4.16-5.36 g/100 g and 7.77-8.44 g/100 g, in oat, respectively.

Among raw cereal grains, barley showed the highest TDF content followed by oat, BNR and WNR. According to Prasadi and Joye[26], the outer layer of grains has a high concentration of dietary fibers, which is usually removed when refining the grain, lowering the dietary fiber content in white rice. This shows the reason for brown rice samples showing higher dietary fiber content compared to white rice

Table 1. Dietary fiber contents in cooked cereal grains (Unit: g/100 g)

Grain	Variety	Raw			Cooked		
		SDF	IDF	TDF	SDF	IDF	TDF
Brown non-glutinous rice (BNR)	Samkwang	0.23±0.02[a]	2.79±0.06[a]	3.02±0.07[a]	N.D[1)]	7.69±0.01[b]	7.69±0.01[b]
	Saeilmi	0.45±0.04[a]	3.31±0.01[a]	3.76±0.03[a]	0.23±0.00[b]	1.45±0.10[b]	1.68±0.10[b]
	Shindongjin	0.46±0.00[a]	3.48±0.01[a]	3.94±0.01[a]	N.D	2.65±0.02[b]	2.65±0.02[b]
	Odae	0.65±0.00[a]	4.50±0.02[a]	5.14±0.02[a]	0.25±0.01[b]	2.09±0.02[b]	2.34±0.01[b]
White non-glutinous rice (WNR)	Samkwang	0.06±0.01[a]	1.77±0.04[a]	1.83±0.03[a]	0.15±0.01[b]	0.70±0.00[b]	0.86±0.01[b]
	Saeilmi	0.13±0.01[a]	2.83±0.08[a]	2.96±0.07[a]	N.D	1.02±0.07[b]	1.02±0.07[b]
	Shindongjin	N.D	1.97±0.08[a]	1.97±0.08[a]	0.04±0.00[b]	0.67±0.03[b]	0.72±0.03[b]
	Odae	0.41±0.03[a]	1.35±0.01[a]	1.75±0.04[a]	0.13±0.01[b]	0.68±0.04[b]	0.81±0.04[b]
Barley	Nurichal	6.15±0.02[a]	5.64±0.21[a]	11.78±0.24[a]	2.36±0.00[b]	N.D	2.36±0.00[b]
	Hogang	5.24±0.04[a]	7.58±0.00[a]	12.82±0.04[a]	3.41±0.00[b]	0.78±0.00[b]	4.19±0.00[b]
	Keunalbori no.1	3.80±0.05[a]	5.73±0.00[a]	9.53±0.05[a]	0.86±0.00[b]	1.03±0.00[b]	1.88±0.00[b]
	Heuksujeongchal	6.17±0.05[a]	6.19±0.09[a]	12.36±0.13[a]	1.77±0.04[b]	1.65±0.00[b]	3.42±0.04[b]
Oat	Daeyang	2.41±0.06[a]	5.36±0.16[a]	7.77±0.22*	1.22±0.01[b]	6.61±0.00[b]	7.83±0.00*
	Joyang	4.28±0.06[a]	4.16±0.00[a]	8.44±0.01*	1.28±0.02[b]	7.20±0.03[b]	8.48±0.05*

Values are expressed as mean ± standard deviation. Means with different letters (a,b) of dietary fiber type by the cooking status in the same row are significantly different at P<0.05 based on independent T-test. The symbol (*) indicates there is no significant difference at P>0.05 based on independent T-test. SDF: soluble dietary fiber, IDF: insoluble dietary fiber, TDF: total dietary fiber.

[1)] Not detected.

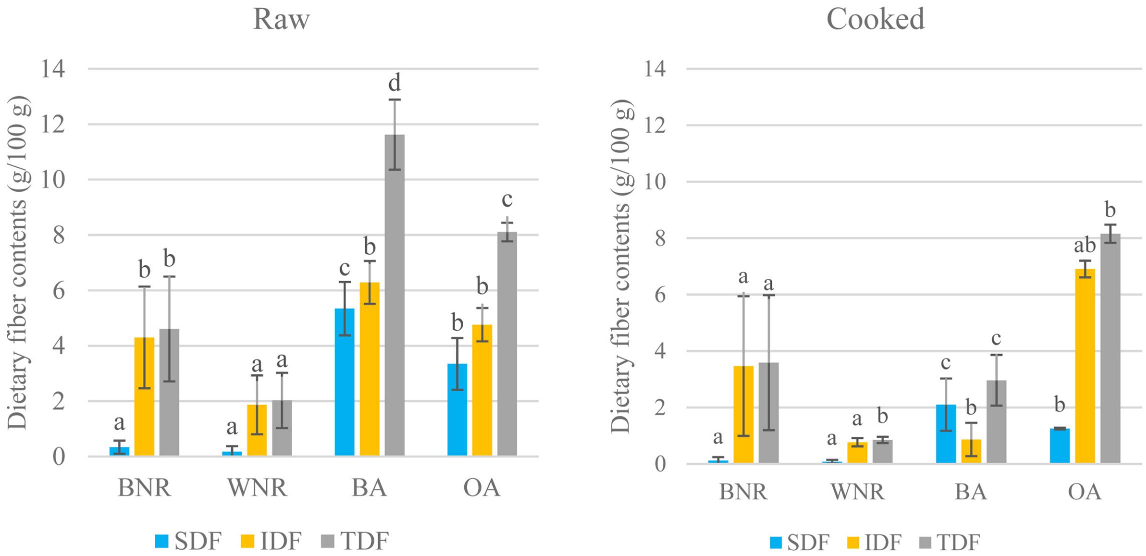

Fig. 1. Average of dietary fiber contents in cereal grains. Bars with different small letters (a-c) are significantly different (*P*<0.05) based on independent T-test. BNR: brown non-glutinous rice, WNR: white non-glutinous rice, BA: barley, OA: oat, SDF: soluble dietary fiber, IDF: insoluble dietary fiber, TDF: total dietary fiber.

samples. A wide range of dietary fiber content is shown in the results, but the various growing condition factors could affect the nutrition component although they are the same type of grains[27,28].

From a study by Lee et al.[28], the SDF of raw oat had a range of 2.51-4.0 g/100 g. For barley, the SDF, IDF, and TDF content were 4.8, 8.6, and 13.4 g/100 g, respectively, according to Beloshapka et al.[29]. WNR and BNR showed a range of 0.6-0.74 g/100 g and 2.8-3.32 g/100 g of TDF in other studies[30,31]. All these studies showed similar dietary fiber content with the results obtained from this study.

Change in dietary fiber contents of cooked cereal grains

The content of SDF, IDF, and TDF each ranged from N.D-0.25 g/100 g, 1.45-7.69 g/100 g, and 1.68-7.69 g/100 g in cooked BNR, and N.D-0.15 g/100 g, 0.67-1.02 g/100 g, and 0.70-1.02 g/100 g in cooked WNR, 0.86-3.41 g/100 g, N.D-1.65 g/100 g, and 1.88-4.19 g/100 g in cooked barley, and 1.22-1.28 g/100 g, 6.61-7.20 g/100 g, and 7.83-8.48 in cooked oat, respectively (Table 1).

The average of SDF, IDF, and TDF in each raw and cooked cereal grains was arranged in Fig. 1. TDF of BNR, WNR and barley decreased after cooking by almost 1, 1.2, and 8.7 g/100 g, respectively. However, the average TDF of raw oat was 8.11±0.34 g/100 g, and cooked oat was 8.20±0.33 g/100 g. SDF of oat decreased by 2.2 g/100 g and IDF increased by 2.2 g/100 g, which did not give a change of TDF. When cereal grains were cooked, oat showed the highest TDF content, followed by barley, BNR and WNR. Also, cereal grains which showed less decrease in dietary fiber rate were cooked oat, cooked BNR, cooked WNR, and cooked barley, by order. These results show that cooked oat could provide up to 8 times as much TDF as cooked WNR. Cooked BNR and cooked oat could help absorb water and improve intestinal health, due to the high content of IDF[30].

Similar results of TDF content in rice were obtained from a study by Trinidad et al.[31], as a range of 0.9-2.1 g/100 g in WNR, and 5.0-5.9 g/100 g in cooked BNR. Dietary fiber contents in barley samples shows a decrease after cooking, but cooked barley samples were the only samples that showed higher SDF compared to IDF among other grain samples. In oat samples, a slight decrease of SDF, and a slight increase in IDF were shown after cooking, making almost no difference in the TDF content. TDF of cooked oat showed a similar range of 2.3-8.5 g/100 g in another study[32].

Free sugar content of raw cereal grains

Among 6 free sugar standards, only sucrose was detected in BNR (0.76-1.27 g/100 g) and WNR (0.09-0.47 g/100 g) (Table 2). Four types of sugar were detected in barely, and the highest concentration of sugar was sucrose, with the range of 0.38-0.89±0.01 g/100 g, followed by raffinose (0.13-0.34 g/100 g), maltose (0.07-0.13 g/100 g), and fructose (N.D-0.09 g/100 g). Oat showed three types of sugar, which were fructose (0.07-0.08 g/100 g), sucrose (0.82-0.84 g/100 g), and raffinose (0.18-0.19 g/100 g). The content of sucrose was the highest among the sugars and followed by raffinose and fructose.

In other studies[33], sucrose of WNR showed the range of 0.94-1.33 g/100 g, and fructose (0.16-0.31 g/100g) was

Table 2. Free sugar content of raw and cooked cereal grains (Unit: g/100 g)

Grain	Variety	Raw				Cooked			
		Fructose	Sucrose	Maltose	Raffinose	Fructose	Sucrose	Maltose	Raffinose
Brown non-glutinous rice (BNR)	Samkwang	N.D[1)]	0.92 ± 0.01^{a}	N.D	N.D	N.D	0.38 ± 0.03^{b}	N.D	N.D
	Saeilmi	N.D	1.00 ± 0.05^{a}	N.D	N.D	N.D	0.40 ± 0.01^{b}	N.D	N.D
	Shindongjin	N.D	0.76 ± 0.00^{a}	N.D	N.D	N.D	0.26 ± 0.01^{b}	N.D	N.D
	Odae	N.D	1.27 ± 0.01^{a}	N.D	N.D	N.D	0.53 ± 0.04^{b}	N.D	N.D
White non-glutinous rice (WNR)	Samkwang	N.D	0.16 ± 0.01^{a}	N.D	N.D	N.D	N.D	N.D	N.D
	Saeilmi	N.D	0.15 ± 0.00^{a}	N.D	N.D	N.D	N.D	N.D	N.D
	Shindongjin	N.D	0.09 ± 0.02^{a}	N.D	N.D	N.D	N.D	N.D	N.D
	Odae	N.D	0.47 ± 0.02^{a}	N.D	N.D	N.D	0.04 ± 0.00^{b}	N.D	N.D
Barley	Nurichal	N.D	0.50 ± 0.01^{a}	0.07 ± 0.00^{a}	0.34 ± 0.00^{a}	N.D	0.08 ± 0.01^{b}	N.D	N.D
	Hogang	N.D	0.38 ± 0.00^{a}	0.08 ± 0.01^{a}	0.26 ± 0.00^{a}	0.07 ± 0.00^{b}	0.07 ± 0.00^{b}	N.D	N.D
	Keunalbori no.1	0.09 ± 0.00*	0.56 ± 0.01^{a}	0.07 ± 0.00*	0.14 ± 0.00^{a}	0.07 ± 0.00*	0.08 ± 0.01^{b}	0.07 ± 0.00*	N.D
	Heuksujeongchal	0.09 ± 0.00^{a}	0.89 ± 0.01^{a}	0.13 ± 0.00*	0.13 ± 0.00^{a}	0.13 ± 0.00^{b}	0.21 ± 0.00^{b}	0.18 ± 0.01*	N.D
Oat	Daeyang	0.07 ± 0.00^{a}	0.84 ± 0.03^{a}	N.D	0.19 ± 0.02^{a}	N.D	0.43 ± 0.01^{b}	N.D	0.10 ± 0.01^{b}
	Joyang	0.08 ± 0.00^{a}	0.82 ± 0.02^{a}	N.D	0.18 ± 0.01*	N.D	0.41 ± 0.00^{b}	N.D	0.09 ± 0.02*

Values are expressed as mean ± standard deviation. Means with different letters (a,b) of free sugar type by the cooking status in the same row are significantly different at $P<0.05$ based on independent T-test. The symbol (*) indicates there is no significant difference at $P>0.05$ based on independent T-test.

[1)] Not detected.

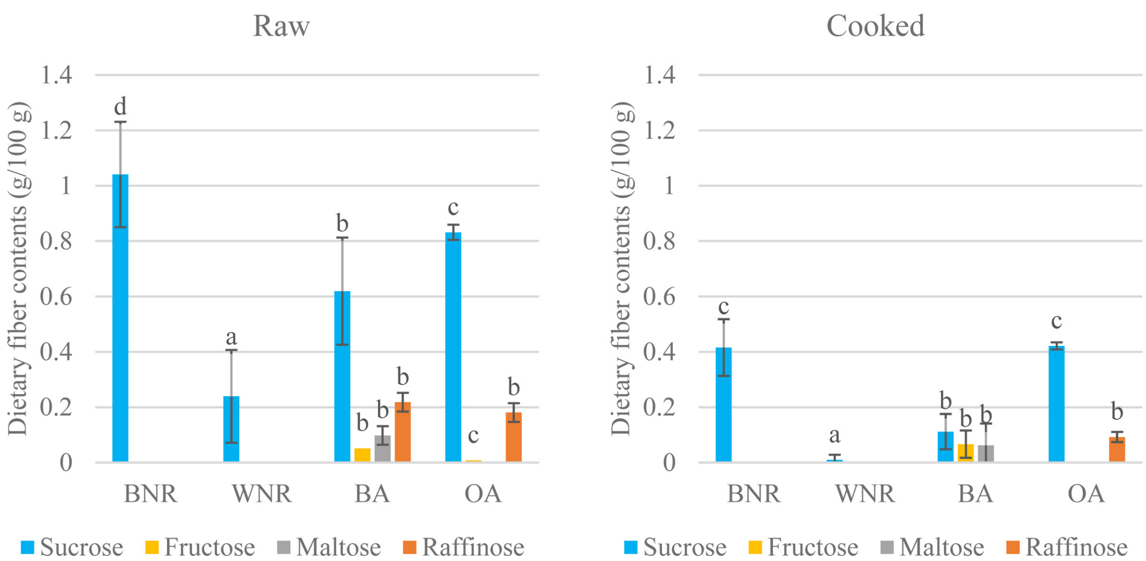

Fig. 2. Average of free sugar contents in cereal grains. Bars with different small letters (a-d) are significantly different ($P<0.05$) based on independent T-test. BNR: brown non-glutinous rice, WNR: white non-glutinous rice, BA: barley, OA: oat.

detected. Barely showed similar results of maltose (0.006-0.14 g/100 g), raffinose (0.14-0.83 g/100 g), and fructose (0.03-0.16 g/100 g), but sucrose (0.34-2 g/100 g) showed a higher content, and also glucose (0.03-0.6 g/100 g) could be detected from a study by Geng et al.[23)]. According to Sugars et al.[24)], 5 types of sugar could be detected in oat. Glucose (0.06-0.07 g/100 g) and maltose (0.01-0.03 g/100 g) as well as fructose (0.02-0.05 g/100 g), sucrose (0.40-0.63 g/100 g), and raffinose (0.16-0.26 g/100 g), were detected. These differences could be shown because of the type of rice breed, change of growing condition, the harvest season and growth rate of grains[24)].

Change of free sugar content in cooked cereal grains

When cereal grains were cooked, sucrose decreased about 0.6 g/100 g in BNR, and almost all the sucrose content decreased in WNR (Table 2). For barely, sucrose (0.07-0.21 g/100 g), and maltose (N.D-0.18 g/100 g) content decreased slightly, and fructose (N.D-0.13 g/100 g) did not show significant change, but raffinose could not be detected after cooking. In cooked oat, sucrose (0.41-0.43 g/100 g) and raffinose (0.09-0.10 g/100 g) decreased almost half of raw oat, and fructose could not be detected anymore. Not much studies about free sugar content of cooked cereal grains were available.

The average of free sugar content in cooked cereal grains could be seen in Fig. 2. All sugar content decreased, especially for sucrose, more than half of the content decreased.

Sucrose could increase antioxidant activities which give health benefits, but too much sugar intake could also cause type 2 diabetes, which makes it important to know how much sugar is consumed[34]. However, the dietary fiber decreases the speed of free sugar absorption, which lowers the glycemic index (GI) as the food is digested[35].

Based on the results of the study, it shows that cooking decreases the content of dietary fiber and free sugar present in WNR, BNR, and barley. Also, these results could provide nutritional values of cereal grains to consumers.

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국문요약

곡류는 대한민국을 비롯한 많은 국가에서 주요 식단으로 자리매김하고 있으며, 여러 형태로 섭취되고 있지만 밥 형태로 익혀 먹는 방법이 가장 흔히 알려져 있다. 쌀과 밥 형태의 국내산 현미, 백미, 보리와 귀리의 식이섬유와 유리당 함량을 분석하고 이들의 변화를 비교하기 위해 해당 연구를 진행하였다. 총 식이섬유 함유량은 보리밥 (11.62±1.26 에서 2.96±0.90 g/100 g)에서 가장 높은 감소율을 보였으며, 귀리 (8.1±0.34 에서 8.1±0.32 g/100 g)는 거의 변화가 나타나지 않을 정로도 차이가 없었다. 이는 귀리의 수용성 식이섬유가 2.1 g/100 g 정도 감소하였지만 불용성 식이섬유의 함량이 2.2 g/100 g 정도 증가하여 총 식이섬유에는 영향을 주지 않은 것으로 나타났다. 현미와 백미에서는 표준당 6종류 중 sucrose만 검출되었으며 현미밥의 sucrose 함량이 약 0.6 g/100 g 감소하였고, 백미밥에서는 검출되지 않았다. Fructose, sucrose와 raffinose가 보리 (0.09, 0.58, 0.22 g/100 g)와 귀리 (0.08, 0.83, 0.19 g/100 g)에서 검출되었으며, 추가로 보리에서는 maltose (0.09 g/100 g)도 함유된 것으로 나타났다. 조리 후에 모든 곡물에서 유리당 함량이 감소한 것으로 나타났다. 이를 통해 곡류를 조리할 시 식이섬유와 유리당의 함량이 감소하는 효과가 있다는 것을 알 수 있다. 본 연구 결과는 다양한 곡류의 조리에 따른 영양 연구에 도움이 될 것으로 판단되며, 일상 식단에 식이섬유 섭취량을 늘리고 싶거나 당분 조절이 필요한 소비자들에게 정보를 제공함으로써 도움이 될 것이라고 여겨진다.

Conflict of interests

The authors declare no potential conflict of interest.

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