Nutritional Properties of Starch in Buckwheat Noodles

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Summary Buckwheat noodles were studied to identify the possibility of reduced starch hydrolysis rate and glucose release after the ingestion of buckwheat meals, in comparison to the wheat-based meals. The rate of starch hydrolysis and the resistant starch (RS) formation in boiled buckwheat noodles (BWN), boiled wheat noodles (WN), boiled buckwheat groats (BWG), and white wheat bread (WB) were evaluated in vitro. The highest content of RS (total starch basis) was found in boiled BWG (6%), compared with the BWN (3.4%), WN (2.1%), and WB (0.8%). The rate of in vitro amylolysis was significantly reduced (p<0.05) in both studied buckwheat products in comparison to the reference WB. The calculated hydrolysis index (HI) was lower in BWN (61) in comparison to WN (71), but higher in comparison to boiled BWG (50). It is confirmed that BWN have some potential in diets designed in accordance with the dietary recommendations for diabetic patients and for healthy subjects.

Key Words buckwheat, starch hydrolysis, groats, flour, noodles

In some parts of the world, buckwheat (Fagopyrum esculentum Moench; BW) is an important constituent of the diet and thus abundantly contributes dietary carbohydrates in different forms. Buckwheat noodles (BWN) are consumed popularly in Japan and traditionally in some rural areas of China (especially in Shanxi and Shaanxi Provinces), in Bhutan, and in the regions of the southern slopes of the European Alps, namely, Slovenia, Italy, Switzerland, and France (1-3). Buckwheat groats (BWG) can be used in a way similar to how rice is used. Groats appear as a traditional food in some mountainous areas of Japan (for example, Shikoku island), and in Slovenia, Croatia, Poland, Ukraine, and Russia (2). A low hydrolysis index and flattened metabolic responses after an ingestion of a BWG meal have been recently confirmed (4).

It is of great interest to improve diabetic control by altering the properties of carbohydrates ingested. A possibility for ranking foods with respect to their potential to raise the blood glucose, in comparison to the reference product [glucose or white wheat bread (WB)], i.e., the glycemic index (GI) concept (5), is available. The metabolic advantages of low-GI diets in a long-term perspective are widely supported (6). It has also been reported that a low-GI meal may cause an improved glucose tolerance after the next meal (7, 8). The so-called second-meal effect could thus appear even during a single day. The slow digestion of food starch has also been connected with prolonged endurance time at strenuous exercise (9) and with prolonged satiety after ingested meals (10). Moreover, a preventive potential against the development of maturity onset diabetes (11, 12) and cardiovascular disease (13, 14) has been connected with the slow digestion and absorption of food carbohydrates.

The starch resistant to amylolytic enzymes also takes part in lowering the postprandial responses of blood glucose. A restricted availability of resistant starch (RS) in foods has been associated with the physical entrapment of starch within structures of grains or food (RS1), native, ungelatinized starch granules (RS2), and starch retrogradation upon the hydrothermal treatment of food (RS3) (15). There is evidence that the substances formed during the fermentation of RS, contribute to the maintenance of colon health and also express beneficial influences on glucose metabolism (6). So foods with higher amounts of RS could be considered as beneficial.

The mechanical characteristics of BWN were recently studied by Ikeda and Asami (3). Very few studies are available regarding the nutritional features of BW starch (4, 15, 16), and no studies were performed on the nutritional characteristics of starch in BWN. The purpose of the present study was to investigate the nutritional properties of starch in BWN in comparison to BWG, wheat noodles (WN), and WB. The rate of starch hydrolysis and the RS formation were analyzed in vitro in boiled BWG, in BWN and WN, and in WB.

MATERIALS AND METHODS

Samples. Commercial samples of dry BWN [made of 100% BW flour (BWF)] and dry WN were purchased in Japan. Whole dehusked BW grains were purchased as a commercial sample in Slovenia. According to the traditional process, BW grains were dehusked after hydrothermal pretreatment and dried to 13.15% moisture level. White wheat flour was purchased at the Swedish local market (Kungsörn, Järna, Sweden).

Buckwheat and wheat noodles. Dried BWN and WN...
(about 90 and 80 g, respectively) were boiled (1 L of water; 1 g salt) for 6 and 10 min, respectively, according to the manufacturer’s instructions. Before analysis, the noodles were drained and cooled (15 min). Their starch content was corrected for the amount of starch lost in water.

White wheat reference bread. We used 450 g white wheat flour, 300 g water, 4 g salt, 4 g dry yeast, and 10 g monoglycerides to make the reference product in a baking machine. The cooled bread was sliced, the crusts removed, and the slices frozen. Before analysis, the slices were thawed at room temperature.

Chemical analysis of the test products. Prior to analysis of portions of the WB, the boiled BWG and boiled noodles were air-dried and milled in a Cyclotec mill (Tecator, Sweden) to a particle size <0.8 mm. The total starch in the raw materials and in the breads was determined enzymatically following solubilization in alkali by a method described by Tovar et al. (17): before the alkali treatment (4 mol/L KOH), however, the samples were soaked in a phosphate buffer (0.1 mol/L; pH 6.0). Because the alkali treatment was omitted (18), starch corrected for retrograded amylase [used for hydrolysis index (HI) standardization] in the milled material was also determined.

Potentially available starch and RS. To mimic the physiological conditions, the in vitro analysis of potentially available starch and RS were performed by parallel determination on wheat bread sample, boiled BWG, and noodles without prior mechanical disintegration, i.e., in the “as eaten” form according to Åkerberg et al. (19). After completed incubation, RS and nonstarch polysaccharides were precipitated with 95% ethanol (v/v) and filtrated through P2 crucibles. In the filtrates, the glucose was measured at 450 nm with glucose oxidase-peroxidase reagent and expressed as potentially available starch. The RS, comprising RS1 + RS2 + RS3, was determined as total starch in dried (105°C overnight) and milled residues.

In vitro rate of starch hydrolysis and HI. The rate of starch hydrolysis in the wheat bread sample, boiled BWG, and noodles was followed by a dialysis procedure (20). The HIs were calculated as the ratio between the area under the hydrolysis curve (0–180 min) for each product and the corresponding area obtained after hydrolysis of the reference WB, expressed in percentage.

Statistical analysis. The results are expressed as means±SE. The potentially available starch, RS, and the in vitro rate of starch hydrolysis were statistically evaluated by one-way ANOVA with the SPSS/PC+ program (SPSS Inc., Chicago, IL, USA). Comparisons between the means were performed by Duncan’s test. A value of \( p<0.05 \) was considered significant.

RESULTS AND DISCUSSION

The nutritional features of BW starch were expected to be comparable with those of true cereal-based products, especially because native BW starch has a characteristic A-type of crystallinity (21), otherwise typical for cereal starches.

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Total starch, RS, and potentially available starch

The total starch, potentially available starch, and RS contents in different BW and wheat products are reported in Table 1. The results for total starch, expressed as a sum of potentially available starch and resistant starch contents, were well in accordance with the one-step starch analysis described by Tovar et al. (17).

In the vitro digestibility of starch in BWN and BWG was higher than 90%, total starch basis. A difference in the RS content between BWN and WN was found to be statistically significant \( (p<0.05) \). However, the highest proportion of RS \( (p<0.05) \) was found in boiled BWG [6.0% (total starch basis)]. This is in agreement with previous in vivo studies (4, 16). It was reported that 4.9 to 6.4% starch of hydrothermally treated and milled BWG passed undigested to the rat hindgut.

The RS content of WN significantly differed from WB. The same appeared when comparing the current RS data for BWN and that reported for BW flour-based breads (4). The higher proportion of RS1, which is likely to be present in pasta products, mostly contributes to differences when comparing RS contents with flour-based breads. Thus again the importance of food structure for the starch accessibility is confirmed.

It is hypothesized, that differences between BWN and WN could be based in various technologies of noodle preparation and/or the result of molecular level. Namely, buckwheat proteins can form a more-compact matrix around starch granules. When this happens, the denaturation of proteins during thermal treatment prevents the swelling of starch granules and consequently enhances the resistance of starch to enzymatic attack.

<table>
<thead>
<tr>
<th>Product</th>
<th>Total starch (% dmb)</th>
<th>Potentially available starch ±SE (% dmb)</th>
<th>RS ±SE (% dmb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WB</td>
<td>81.2</td>
<td>78.4 ±0.5c</td>
<td>0.8 ±0.0a</td>
</tr>
<tr>
<td>WN</td>
<td>80.2</td>
<td>78.8 ±0.6c</td>
<td>2.1 ±0.1b</td>
</tr>
<tr>
<td>BWN</td>
<td>74.9</td>
<td>74.4 ±1.2b</td>
<td>2.6 ±0.1c</td>
</tr>
<tr>
<td>BWG</td>
<td>72.8</td>
<td>67.9 ±0.4a</td>
<td>4.4 ±0.2d</td>
</tr>
</tbody>
</table>

1 Values are means of two parallel determinations.
2 Values are means±SE; \( n=6 \).
3 Means not sharing the same letter in the columns are significantly different \( (p<0.05) \).
Accordingly, HI of WN (70.6) did not differ from HI of BWN. Previously, it was shown (4) that the replacement of 30% wheat flour in bread with BWF surprisingly reduced the HI. This finding suggests that starch in buckwheat products may behave differently from starch in other flour-based cereal products; it might be that BW itself contains one or more components that could inhibit the amylolytic degradation of BW starch. Ikeda et al. (22) studied the inhibitory activity of BWF extract on amylases from different sources. However, the authors hypothesized that the inhibitory substance might be of protein origin. Thus it is expected that during the boiling of BWN and BWG, this inhibitory potential might be reduced. Therefore in our case more stable inhibitory substances, such as tannins and phytic acid, might inhibit starch degradation. BW is an especially abundant source of tannins (2.5%) and phytic acid (0.2-0.7%, dmb; unpublished results), which may potentially contribute to the reduced in vitro rate of starch hydrolysis (23-29).

The calculated HI of bread with the same proportion of wheat flour and whole BWG was 71 as published by Skrabanja et al. (4). The corresponding glycemic and insulinemic indices were 66 and 74, respectively. From the present study, it is assumed that HI in BWN (HI=61) was low and might predict lower metabolic responses in vivo. However, there are still technological difficulties in producing pure (100%) BW pasta.

The present study confirms that BW has a potential use in foods designed with a modified course of starch digestion. BWN or boiled BWG may influence the metabolism beneficially in comparison to the WB. Among products studied, boiled BWG, followed by BWN, are therefore most in accordance with current dietary recommendations for diabetic patients and for healthy subjects.

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REFERENCES


