Texture and Digestion Properties of Cooked Rice and Rice Noodles

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Abstract

Rice varieties high in amylose content have low glycemic and insulin responses. Rice noodles are processed by extrusion from high amylose content rice, which may also have low glycemic and insulin responses. In this study, cooked rice and rice noodles processed from two high amylose content cultivars, Guangluai4 (GL4) and Zhenguiai (ZGA), were chosen for in vitro starch digestion evaluation. Apparent amylose content of cultivars (i.e., GL4-28.4% and ZGA-26.8%) and pasting properties except final viscosity were significantly different between the cultivars. In vitro starch digestion results showed that the glucose production rate in rice noodles was significantly slower than that in cooked rice by 65.7% and 42.0% in GL4 and ZGA, respectively. The main reason for low glucose production in rice noodles was active digestion duration longer in rice noodles than in cooked rice, which reflects the slow release of glucose during starch digestion. The texture of rice noodles in the GL4 and ZGA cultivars is 3 and 2.3 times harder than that of cooked rice, respectively. Thus digestive enzymes can hardly enter the interior of rice noodles for amylolysis. As a result, the digestion time of rice noodles is longer, and the release of glucose during digestion is slower than that of cooked rice. The slower release of glucose during rice noodle digestion may be beneficial for prolonging satiety and reducing food intake. Consequently, eating rice noodles may help in improving or preventing diabetes and obesity over time.

Introduction

Rice (*Oryza Sativa* L.) is the staple food for more than 65% of the population in China [1]. After enzymatic amylolysis, a starch-rich grain (containing more than 90% starch in dry matter) causes a remarkable increase in glucose levels in the blood [2–4]. As living standards improve, the demand for good taste and soft rice is rapidly increasing. However, the amylose content in the grains of the cultivated rice varieties is generally less than 15% [5,6]. Rice varieties with a low amylose content raise blood glucose much faster than those with high amylose content [7–9]. Therefore, maintaining our preference for the low amylose content rice for extended periods raise the risk of developing Type 2 diabetes [10,11]. On the other hand, eating high amylose rice is not well accepted by consumers, mainly because of the firm texture and unappealing taste [12–14]. Therefore, there is a dilemma between health and mouthfeel.

To address the issues mentioned above, rice noodles as a substitute for cooked rice may be an alternative because they are made from rice varieties with intermediate to high amylose content (>22%) [15,16]. Moreover, the intake of rice noodles is a good choice for diabetic patients [17–19]. On the other hand, rice noodles have a smooth, soft and delicate taste and a certain elasticity and viscosity [20] and are the most consumed form of rice product next to cooked rice in Asia[21]. However, there is a limited literature comparing the starch digestibility between cooked rice and rice noodles made from high amylose content varieties.

The primary objective of this study was to characterize the differences in starch digestibility between cooked rice and rice noodles made from two high amylose rice cultivars. Understanding these differences may help in the development of more rice products with slow glucose release.

Results

There were significant differences in amylose content and pasting properties such as peak, trough, breakdown, setback viscosity, peak time and pasting temperature between GL4 and ZGA rice flour (Table 1). The amylose content of GL4 was 6.2% higher that of ZGA. Peak viscosity and trough viscosity were 10% and 25% lower in the GL4 than in the ZGA, respectively. Meanwhile, breakdown and setback viscosity was 48% and 23% higher in the GL4 than the ZGA cultivar, respectively,. In addition, the time to peak viscosity was 10% longer in the ZGA cultivar, while the pasting temperature was 2% higher in the GL4 cultivar.

Table 1
Physicochemical and paste properties of milled rice flour

Parameter	GL4	ZGA
physicochemical properties		
Total starch (%,DW)	86.5±0.1	86.0±1.1
Amylose content (%,DW) *	28.4±0.7	26.8±0.6
Protein content (%,DW)	9.1±0.8	9.0±0.7
Gel consistency (mm)	38±3	33±3
Pasting properties		
Peak viscosity (cP) *	3312±53	3630±52
Trough viscosity (cP) *	2433±136	3037±60
Breakdown (cP) *	879±84	594±26
Final viscosity (cP)	4430±127	4542±28
Setback(cP) *	1118±74	911±31
Peak Time (min) *	5.75±0.04	6.35±0.04
Pasting temperature (°C) *	81.0±0.5	79.5±0.5

Simple arithmetic means of three replicates ± standard deviation, followed by * differ in the same row by the T test ($p \leq 0.05$). DW represents dry weight; GL4 represents guangluai4, ZGA represents zhengguiai cultivar.

Rice noodles from both varieties had significantly higher ($p < 0.05$) moisture content and texture properties, such as hardness, springiness, chewiness, cohesiveness and resilience than cooked rice in both cultivars as shown in Table 2. Moisture content was 6.3% and 5.9% higher in cooked rice than in rice noodles for GL4 and ZGA, respectively. Hardness was 67% and 57% lower in cooked rice than in rice noodles for GL4 and ZGA, respectively. Similarly, springiness was lower in cooked rice than in rice noodles by 14% for GL4 and 21% for ZGA. The chewiness was 77% and 73% lower in cooked rice than in rice noodles for GL4 and ZGA, respectively. The cohesiveness was 19% and 21% lower in cooked rice than in rice noodles for GL4 and ZGA, respectively. In addition, resilience was also lesser in cooked rice than in rice noodles, by 18% for GL4 and 20% for ZGA.

Table 2
Moisture content and texture properties of cooked rice and rice noodles

Cultivar	Processing type	Moisture content(%)	Textural properties				
			Hardness (g)	**Springiness (g)**	**Chewiness (g)**	**Cohesiveness**	**Resilience**
GL4	Cooked rice	66.2±0.1a	1347±30c	0.74±0.02b	629±16c	0.62±0.02b	0.46±0.01c
	Rice noodle	62.3±0.6b	4083±751a	0.86±0.02a	2685±456a	0.76±0.02a	0.56±0.02ab
ZGA	Cooked rice	66.9±0.4a	1224±12c	0.72±0.03b	563±32c	0.64±0.02b	0.46±0.01bc
	Rice noodle	63.1±1.6b	2854±218b	0.91±0.01a	2092±121b	0.81±0.01a	0.57±0.01a

Values followed by the same letters within the column are not significantly different at $p \leq 0.05$. Data are mean ± standard deviation (n = 3). GL4 is Guangluai4 cultivar and ZGA is Zhenguiai cultivar.

There was a significant difference in active digestion duration (ADD) and the rate of glucose production (GPR) between cooked rice and rice noodles for both GL4 and ZGA (Table 3). For GL4 and ZGA cultivars, rice noodles had lower ADD than its cooked rice by 61% and 53%, respectively. Total glucose production (TGP) was slightly higher, but there was no significant difference in cooked rice than rice noodles for GL4, while TGP was significantly lower by 22% in cooked rice than rice noodles for ZGA. In addition, the GPR was significantly faster in cooked rice than rice noodles by 192% for GL4 and 72% for ZGA.

Table 3
ADD, TGP and GPR in high amylose rice GL4 and ZGA

Cultivar	Processing type	Digestion properties		
		ADD (min)	**TGP (mg/g sample)**	**GPR (mg/g sample/ min)**
GL4	Cooked rice	202±38b	339±16b	1.7±0.3a
	Rice noodle	513±96a	302±61b	0.6±0.0b
ZGA	Cooked rice	233±48b	325±3b	1.4±0.3a
	Rice noodle	498±43a	415±18a	0.8±0.0b

Values represent the means ± standard deviation of a replicated experiment. The same letters within the column are not significantly different at $p \leq 0.05$. GL4 is Guangluai4 cultivar and ZGA is Zhenguiai cultivar. ADD represents active digestion duration, TGP represents total glucose production, GPR represents glucose production rate.

Discussion

In this study, we found a significant difference in texture properties and in vitro digestion among cooked rice and rice noodles made from two high amylose content rice cultivars, GL4 and ZGA. All indexes relating to the textural properties of rice noodles were considerably higher than those of cooked rice processed from the same cultivar. Moreover, the active digestion duration (ADD) and the rate of glucose production (GPR) showed significant variations among the rice noodles and the cooked rice made from the same cultivar. In both variaties, rice noodles have a longer ADD and a slower GPR than cooked rice. However, the TGP in rice noodles made from the ZGA cultivar was maximum than in the cooked rice processed from the same cultivar after four hours. As a reference, in vivo digestion takes two hours[22], and most of the produced glucose was excreted or absorbed after four hours. As a result, a slightly higher TGP can be ignored over a longer ADD. In addition, the variation in GPR was primarily due to the longer digestion time (GPR=TGP/ADD) in this study. The possible explanation for prolonged digestion time is that the texture of rice noodles was harder than cooked rice, and digestive enzymes could hardly enter the interior for amylolysis[23]. Therefore, our findings showed that the glucose concentration of the in vitro digested rice noodles reached the maximum value was significantly lower than that of cooked rice, which is essential for controlling blood glucose for diabetic patients[19].

There was a slight difference in the in vitro digestion of cooked rice with high amylose content, but the variation was significant after processing into rice noodles, which might be attributed to the changes in the molecular structure during processing rather than the high amylose content and pasting properties[24]. Although this study provides valuable results, further investigations are required to comprehensively understand the slowly digested rice products.

Conclusions

Rice noodles made from high amylose varieties can decrease the rate of starch digestion than cooked rice. This may be related to its hard texture by extrusion processing method. Furthermore, high amylose rice noodles may be considered as lower GI food and it may be a beneficial food not only for people with chronic diseases such as diabetes, hyper lipidemia and obesity but also normal individuals.

Methods

Two high-amylose *indica* rice cultivars, i.e., Guangluai4 (GL4, 28.4% amylose) and Zhenguiai (ZGA, 26.8% amylose), were used in this experiment. GL4 and ZGA were grown and harvested in Yongan Town (28°09’N, 113°37’E, 43 m asl), Hunan Province, China, in 2019. The use of plants in this study complies with institutional, national, and international guidelines and legislation.The two cultivars were seleted because they have a wide various physicochemical and pasting properties (Table 1).After harvesting, grains of both cultivars were stored for three months in a well-ventilated place at room temperature, then dehulled and milled using a Milled Rice Testing Machine (JGMJ8098, Jiading Co., Shanghai, China) to obtain milled rice.

About 50 g of milled rice flours (100 mesh) were prepared for each sample to measure physicochemical properties(total starch, amylose content, protein content and gel consistency) and pasting properties (peak viscosity, trough viscosity, breakdown, final viscosity, setback, peak time and pasting temperature). Total starch content was measured using an auto digital polarimeter (P850 Pro; Jinan Hanon Instruments Co., Ltd., Jinan, China). Amylose content, protein content and gel consistency were determined according to Huang et al. [25]. Pasting properties of rice flour were measured using a Rapid Visco Analyzer (RVA-Super 4; Newport Scientific Pty Ltd., Warriewood, Australia).

Each milled rice samples were divided into two parts, one part was processed into cooked rice, the other part was processed into rice noodles.The brief procedure of cooked rice processing was to wash 10 mg of milled rice three times with distilled water, and excess water was removed using a sieve. After washing, milled rice was soaked in distilled water (water to rice mass ratio is 1.6:1) for 30 min at 25°C with a water/rice ratio of 1.6:1 (w/w) and then steamed for 40 min in an electric rice cooker (GDF-2003, Gree Co., Zhuhai, China). The cooked rice sample was left undisturbed for 20 min after the rice cooker was turned off. The cooked rice noodles was made using the commercial method, which primarily uses high-amylose rice as a raw material without any additives. The rice noodles was processed according to the method of Huang et al.[26].

Three grains of cooked rice or rice noodles were placed on a texture analyzer's sample plate (Rapid TA^+, Tengba Co., Shanghai, China). To analyze its texture properties, used a texture profile analysis (TPA) mode. A cylinder-type plunger (10 mm diameter) compressed the rice grains at a crosshead speed of 0.5 mm sec^{-1} at a strain of 50%. The surfaces of the samples were compressed at 6-7 points, and the average of the obtained values was calculated. The results were presented as mean±standard deviation. The following characteristics were determined: hardness, springiness, cohesiveness, chewiness, and resilience.

Starch digestion properties of cooked rice were measured using an in vitro procedure[27]. In brief, samples (cooked rice or rice noodles) were placed in the simulated masticator's base (Zyliss, Zurich, Switzerland). Samples were chopped 20 times to reduce their sizes to about 2-3 mm. A total of 100 ± 1.0 mg of the chewed sample was transferred into a sample cup of the in vitro digestion simulator machine (Nutri Scan GI20, National Instruments, Australia) with a stirrer bar and kept in a heating block to keep the temperature at 37°C. Three enzyme solutions (α-amylase, Pepsin, and Trypsin) were added to each sample cup in a specific sequence along with buffer solutions (0.02M NaOH and 0.2M Sodium acetate). Following digestion of the samples, a Glucose Analyser (GM9, Analox, British) was used to measure the amount of glucose released from these digested samples at six successive time points of 15, 60, 120, 180, 240, and 300 min.

The kinetics of starch digestibility was described using a non-linear model[28]. The first order equation:

$y = a(1- e^{-bx})$

where x is the digestion time (min), y is the amount of produced glucose (mg/g sample) at x is the time, a is the final amount of the produced glucose after 300 min, and b is the constant kinetic parameter. Parameters a and b were estimated using the Curve Expert software 1.4 (Hyams Development, Chattanooga, TN, USA) based on the data obtained from the in vitro digestion procedure. Then, the total glucose production (TGP, mg/g), active digestion duration (ADD, min) and the glucose production rate (GPR, mg/g/min) were calculated according to Huang's method[26].

Analysis of variance (ANOVA) was conducted to test for significant changes in texture properties and in vitro kinetics of starch digestion of cooked rice and rice noodles using SPSS software version 26.0 (IBM, Armonk, NK, USA). All analyses were carried out in triplicate.The least significant difference (LSD) test at $p < 0.05$ was used to detect significant differences among the data.

Declarations

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Conntributions

All experimental work and statistical analyses were designed by Liqin Hu and Min Huang. Liqin Hu, Zhengwu Xiao, Jialin Cao performed the research.Liqin Hu and Jiana Chen analyzed the data and interpreted the results.Liqin Hu prepared tables and drafted the manuscript. Anas Iqbal, Salah F. Abou-Elwafa and Min Huang edited the manuscript.

All authors were involved in reviewing the paper and contributed to the preparation of the final manuscript. All authors read and approved the final manuscript.

Ethics declarations

Competing interests

The authors declare no competing financial interests.

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