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Physicochemical property and glycemic response of chiffon cakes with different rice flours

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ABSTRACT

Three commercial rice flours (indica, japonica and glutinous) were applied to prepare the whole rice cake in chiffon style in comparison to that made of low gluten wheat flour. Not only the *in vitro* and *in vivo* digestion investigations but also the physicochemical properties were discussed. The contents of rapidly digestible starch in rice cakes were ranged in 38%–45%, and the contents of resistant starch were complementary to locate in 55–62% since the slowly digestible starch was very limited. The *in vitro* tests based on white bread as a reference food resulted rice cakes in low-to-middle GI foods by Granfeldt and Goni models, while the *in vivo* test based on the glucose as a reference food showed the rice cakes and wheat cake satisfied the low GI criteria. Transferred Goni model described a good consistency to the *in vivo* result. Specific volume of indica rice cake was resembling to that of wheat cake, and they were both higher than the other two rice cakes. Color measurement of all cakes performed similar to one another. Texture test revealed that the fresh indica cake had lowest hardness and chewiness as well as higher resilience and springiness than the other rice samples. After 24-h storage, the hardness and chewiness of indica cake turned to higher than the other rice cakes due to the fast aging.

1. Introduction

Starch is one of the most abundant carbohydrate in the world, and it is also a major polysaccharide source in daily diets. On the consideration of nutrition and physiological digestion, starch can be classified as rapidly digestible starch (RDS), slowly digestible starch (SDS) and resistant starch (RS) (Englyst, Kingman, & Cummings, 1992). The RDS denotes the starch which can be digested and absorbed in 20 min as it was consumed. Most processed foods of starch are classified as RDS. RDS plays an important role on supply of energy to the human body due to it can be quickly utilized. The SDS expresses the starch digested by the gastrointestinal system within 20–120 min, which can avoid the abrupt increase of blood glucose and, thus, sustain a stable glycemic response. Resistant starch describes the starch which cannot be digested by a healthy human body in 120 min; however, it can be utilized and fermented by the bacteria in the large intestine to maintain a low pH environment and then to reduce the risk of colon cancer (Sajilata, Singhal, & Kulkarni, 2006). Both the SDS and RS act as the substantial characters to maintain the stability of postprandial glycemia. Nowadays RS is defined as the starch cannot be digested and absorbed by the small intestine for a healthy human body (Sajilata & Singhal, 2005).

Due to the indigestible property of RS, starch foods with high RS content can postpone and stabilize the concentration increment of postprandial blood glucose, which is very important to the patients with glucose intolerance (such as diabetics) (Parada & Aguilera, 2011; Shukla, 1995). In fact, the glycaemia response of starch foods is deeply influenced and concern with the starch types, additives, processing methods, and storage environment (Chiu & Stewart, 2013; Deng et al., 2010; Haub, Hubach, Al-Tamimi, Ornelas, & Seib, 2010; Rosen, Ostman, & Bjorck, 2011). The concept of glycemic index (GI) was pioneeringly introduced by Jenkins et al. (1981) in an attempt to classify carbohydrate-based foods according to their postprandial glucose response. The glycemic index is defined as the incremental area under the curve (AUC) for the consumption of test food with carbohydrate content of 50 g in 2 h expressed as a percentage relative to the response after glucose or white bread taken by the same subject (Jenkins et al., 2002; Roberts, 2000). It was reported that long-term diets of high GI foods resulted in the increase risk of chronic diseases such as

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obesity, NIDDM (noninsulin-dependent diabetes mellitus) and cardiovascular disease (Frost & Dornhorst, 2000; Marques et al., 2007; Ludwig, 2000, 2002); inversely, low GI diets revealed to stabilize the postprandial glucose response and to low the risk of metabolic diseases (Brand-Miller, 2007; Hodge, English, O'Dea, & Giles, 2004; Jenkins, 2007; Rizkalla, Bellisle, & Slama, 2002).

Rice, *Oryza* sativa (Asian rice), is a widely consumed staple food for a large part of the human population, especially in East Asia. Cooked rice and the rice product are generally recognized as easily digested for the human body, and non-allergic due to the ordinary composition and gluten free. Hence most cooked rice and rice product are classified as high GI food and suggested to avoid consuming by the glucose intolerance patients since they might cause a prompt increase of postprandial glucose concentration. However, the GI or corresponding glucose response of starchy foods were profoundly related to the ingredients and/or the processing treatments (Adeleye, Ologhobo, & Lji, 2014; Hu, Zhao, Duan, Linlin, & Wu, 2004), which could not directly result only from the GI of the isolated starch component in consumed food but have to investigate scientifically together with the other ingredients.

In Taiwan, rice is a staple food, however, the consumption is declining in decades; it was reduced from 80.18 kg/year/person in 1985 to 46.18 kg/year/person in 2010, which is seriously influencing the food supply chain. To improve the rice consumption, such as diversification of rice products, is very important. In the present study, we applied commercial rice flours to prepare chiffon rice cake and to investigate their physicochemical property and glycemic response in comparison with the wheat cake. Three varieties of rice flours were used, indica, japonica, and glutinous, which the amylose contents were quite different. Influence of amylose content on the physiochemical properties and both *in vivo* and *in vitro* digestion tests were discussed. Due to the *in vitro* enzymatic hydrolysis, the estimated glycemic index (eGI) was resulted from the hydrolysis index (HI) by the relations suggested by Granfeldt, Bjorck, Drews, and Tovar (1992), Goni, Garcia-Aionso, and Saura-Calixto (1997) and Deepa, Singh, and Naidu (2010), respectively, and furtherly to compare to the GI from *in vivo* test. Finally, the classification of rice cakes was proposed for a reference of consumers.

2. Materials and methods

2.1. Raw materials

Commercial rice flours (indica, japonica, and glutinous) were purchased from Gu Tong Foods Ind. (Chia-yi, Taiwan). Low gluten wheat flour was purchased from Ta Fong Flour Mill Co. (Taichung, Taiwan). All flours were sieved by the 40-mesh Tylor sieve in advance, and the proximate compositions analyzed according to AACC methods (2000) were listed in Table 1. Soybean oil was purchased from Taiwan Sugar Corp. (Kaoshong, Taiwan).

2.2. Chemicals

All chemicals were in analytical grade and purchased from Sigma–Aldrich China, Inc. (Shanghai, PR China). The resistance assay (K-RSTAR) and glucose oxidase-peroxidase reagent (K-GLUC) were purchased from Megazyme International Ireland Ltd. (Wicklow, Ireland).

2.3. Preparation of rice cake

The rice cake was prepared in chiffon style with the formulation: rice or wheat flour 100 g, sugar 100 g, egg 280 g, milk 45, soybean oil 30 g, and salt 2 g. Temperature of convection oven was set at 160 °C for 25-min baking. Cake made of low gluten wheat flour was selected as the reference. Cake samples were cut as a cube by side length of 1 cm for the *in vitro* hydrolytic test. The proximate compositions of all cakes were listed in Table 1. Moisture contents of cake were ranged in 45.30–47.00%, crude protein 6.56–6.89%, crude lipid 9.33–9.95%, crude ash 0.94–1.11, and the calculated carbohydrate 35.80–37.72%; the variance of proximate composition between samples was slightly. Here, the carbohydrate content was a necessary parameter for both the *in vivo* and *in vitro* tests of glycemic response.

Table 1
Proximate composition of flours and cakes.

Component	Wheat (low gluten)	Rice		
		Indica	Japonica	Glutinous
Flours				
Moisture	13.53 ± 0.17^{a}	12.56 ± 0.11^{b}	11.88 ± 0.20^{c}	13.25 ± 0.20^{a}
Protein	8.22 ± 0.29^{a}	6.88 ± 0.02^{b}	6.01 ± 0.33^{c}	4.69 ± 0.05^{d}
Lipid	0.80 ± 0.08^{a}	0.29 ± 0.04^{b}	0.70 ± 0.07^{a}	0.22 ± 0.03^{b}
Ash	0.43 ± 0.02^{a}	0.16 ± 0.01^{c}	0.32 ± 0.00^{b}	0.16 ± 0.19^{c}
Carbohydrate	77.01 ± 0.18^{d}	80.11 ± 0.08^{c}	81.09 ± 0.15^{b}	81.67 ± 0.19^{a}
AC	18.25 ± 0.57^{b}	25.46 ± 0.42^{a}	8.90 ± 0.82^{c}	2.61 ± 0.15^{d}
RS*	0.64 ± 0.09^{b}	0.88 ± 0.05^{a}	0.84 ± 0.07^{a}	0.57 ± 0.03^{b}
Cakes				
Moisture	46.34 ± 0.18^{b}	45.30 ± 0.13^{c}	46.79 ± 0.38^{a}	47.00 ± 0.18^{a}
Protein	6.74 ± 0.07^{a}	6.56 ± 0.22^{a}	6.81 ± 0.53^{a}	6.89 ± 0.09^{a}
Lipid	9.95 ± 0.07^{a}	9.92 ± 0.12^{a}	9.33 ± 0.09^{b}	9.42 ± 0.20^{b}
Ash	1.11 ± 0.01^{a}	0.94 ± 0.00^{c}	0.98 ± 0.01^{b}	0.94 ± 0.01^{c}
Carbohydrate	35.80 ± 0.05^{b}	37.72 ± 0.60^{a}	36.38 ± 0.45^{b}	36.11 ± 0.16^{b}

AC = Apparent amylose content (d.b.), RS* = Resistant starch (d.b.).
Values represent Mean ± SD (n = 3).
Values in a row for each sample with different superscripts are significantly different ($p < 0.05$).

2.4. Determination of amylose

The amylose content was determined by an iodine potentiometric titration described by BeMiller (1964) with modifications. The starch sample (100 mg) together with amylose (25 mg) and amylopectin (200 mg) standards (25 mg) were weighed into a 50 mL beaker and dispersed by distilled water (1 mL). Ten milliliters of 1 N KOH was added and the mixture was stirred magnetically at room temperature until complete dispersion of the starch. Another 10 mL of 1 N KOH was added and stirred at 4 °C for 30 min or until the sample completely dissolved. Twenty milliliters of distilled water was added to condition the concentration of KOH to 0.5 N. Ten milliliters of dispersion along with 75 mL of distilled water, 10 mL of 1 N HCl, and 5 mL of 0.4 N KI was transferred to a 150 mL titration beaker, which was installed on the auto-titrator for titration with 8.33×10^{-4} M KIO_3. An auto-titrator (877 Titrino plus, Metrohm AG, Switzerland) equipped with AG9101 platinum electrode was used for the titration of dispersed starch solution at room temperature. Titrant addition was at 0.05 mL/s until the current reached 2.5 μA. The plot of current variation versus quantity of titrant was constructed. The titrant volume, eliminating the volume of blank test, at turning point was determined by extrapolation. The amylose content was determined by the calibration curve, which was built by the above procedure with amylose/amylopectin ratios of 0, 20, 40, 60, 80, 100 wt%.

2.5. Enzyme and preparation of enzyme solution

Porcine pancreatic alpha-amylase (no. 7545) and amyloglucosidase (no. 9913) were purchased from Sigma–Aldrich (St Louis, MO). Alpha-amylase of 6 g was dispersed in 40-mL deionized water by magnetic stirring for 10 min. The dispersion was then

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