ค่าดัชนีน้ำตาลข้าวกข 43 และข้าวหอมมะลิ และการตอบสนองของระดับน้ำตาลและอินสุลินในอาสาสมัครสุขภาพดี: การศึกษาแบบไขว้

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บทคัดย่อ

บทนำ : ข้าวเป็นอาหารหลักของประชากรโลกโดยเฉพาะในทวีปเอเชีย โดยเป็นธัญพืชที่มีสารอาหารหลายชนิดทั้งคาร์โบไฮเดรต โปรตีน กรดไขมัน วิตามินและเกลือแร่

วัตถุประสงค์ : การศึกษานี้มีวัตถุประสงค์เพื่อศึกษาค่าดัชนีน้ำตาลของข้าวกข43 และข้าวหอมมะลิในอาสาสมัครสุขภาพดี และศึกษาการตอบสนองของระดับน้ำตาลและอินสุลินหลังรับประทานข้าว

วิธีการศึกษา: การศึกษาแบบไขว้ในรูปแบบเปิด 3 ช่วงประกอบด้วยช่วงที่รับประทานข้าวกข43 ข้าวหอมมะลิ และสารละลายกลูโคส แต่ละช่วงห่างกัน 1 สัปดาห์ อาหารที่ใช้ทดสอบแต่ละชนิดให้ค่าคาร์โบไฮเดรต 50 กรัม คิดเป็นข้าวหุงสุก 150 กรัม อาสาสมัครได้รับการตรวจเลือดขณะอดอาหารและหลังรับประทานอาหารทดสอบที่เวลา 15, 30, 45, 60, 90 และ 120 นาที

ผลการศึกษา : อาสาสมัครสุขภาพดีจำนวน 16 ราย (เพศชาย 5 รายและเพศหญิง 11 ราย) เข้าร่วมจนจบการศึกษา หลังจากตัดอาสาสมัครที่มีค่าดัชนีน้ำตาลอยู่นอกช่วงค่าเฉลี่ย ± 2 เท่าของส่วนเบี่ยงเบนมาตรฐานแล้วเหลือข้อมูลสำหรับวิเคราะห์จำนวน 11 ราย ระดับน้ำตาลหลังการรับประทานข้าวกข43 มีค่าน้อยกว่าระดับน้ำตาลหลังการรับประทานข้าวหอมมะลิอย่างมีนัยสำคัญตั้งแต่ 30 นาทีถึง 120 นาที เมื่อเปรียบเทียบกับสารละลายกลูโคส 50 กรัมซึ่งใช้เป็นอาหารอ้างอิงพบว่าค่าดัชนีน้ำตาลของข้าวกข43 และข้าวหอมมะลิเท่ากับ 56.9 ± 11.3 และ 80.1 ± 15.8 ตามลำดับ และพบว่าพื้นที่ใต้โค้งของระดับน้ำตาลหลังการรับประทานของข้าวกข 43 มีค่าน้อยกว่าข้าวหอมมะลิอย่างมีนัยสำคัญที่ร้อยละ 28.8 ($p < 0.05$) ส่วนการตอบสนองของระดับอินสุลินภายหลังการรับประทานข้าวกข43 น้อยกว่าข้าวหอมมะลิร้อยละ 19.1 (p =0.19)

สรุป : ข้าวกข43 มีค่าดัชนีน้ำตาลต่ำกว่าข้าวหอมมะลิ จึงเป็นทางเลือกของผู้ที่ต้องการบริโภคข้าวที่ช่วยชะลอระดับน้ำตาลในเลือด (TCTR20210524005)

คำสำคัญ : ข้าวกข43 หลังอาหาร การตอบสนองของระดับน้ำตาลในเลือด

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Determination of Glycemic Index of RD43 Rice and Thai Hom Mali Rice and Effects on Postprandial Glucose and Insulin Responses in Healthy Participants: A Crossover Study

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Abstract

Background: A large portion of the world, particularly in Asia, relies on rice as a staple diet. This kind of cereal grain contains numerous nutritional components including carbohydrates, proteins, certain fatty acids, and micronutrients. This study aimed to determine the glycemic index (GI) of and "RD43" rice and Thai Hom Mali (THM) rice in healthy subjects, and also the postprandial glycemic and insulin responses after consumption.

Method: In a single-sequence, open-label, 3-period, crossover study, each participant orderly received RD43 rice, THM rice and glucose solution which were separated by 1-week washout. Each test meal provided 50 g of available carbohydrates, corresponding to approximately 150 g of cooked rice. Blood collections were taken in the fasting state and at 15, 30, 45, 60, 90, and 120 min after consumption.

Results: Sixteen healthy participants (5 men and 11 women) completed the study. After excluding subjects whose GI values fell outside the range of mean ± 2SD, data from the remaining 11 participants were analyzed. Consumption of RD43 rice resulted in significantly lower postprandial plasma glucose and insulin levels from 30 minutes after eating throughout the 120-minute test when compared to THM rice. In comparison with 50 g of glucose, as a reference, the GI of RD43 and THM rice was 56.9 ± 11.3 and 80.1 ± 15.8 respectively. RD43 group resulted in a 28.8% lower glycemic area under the curve (AUC) response than THM rice ($p < 0.05$). The insulinemic response to RD43 rice was 19.1% lower than THM rice, though this difference did not reach statistical significance (p =0.19).

Conclusion: The results indicate that RD43 has a lower GI and can be an option for rice which reduced glycemic response in healthy subjects. (TCTR20210524005)

Keywords: RD43 rice, postprandial, glycemic response

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Introduction

The overall management of diabetes necessitates nutritional therapy, and carbohydrate intake has a vast influence on blood glucose levels. Based on various proportions of sugars, starches, and fiber, foods containing carbohydrates have a wide range of impacts on glycemic response. Some create a lengthy rise and delayed fall of blood glucose concentrations, while others result in a sudden surge followed by a quick decline[1] The American Diabetes Association (ADA) recommendation about dietary allowance for carbohydrates in adults with diabetes have placed an emphasis on nutrient-dense, high-fiber and minimally processed forms of carbohydrates[2]

Carbohydrates are the most significant dietary energy source for the majority of populations since they are a readily available source of energy in the body. Also, they are the main dietary factor that affects postprandial blood glucose[3] Only carbohydrates can directly raise postprandial blood glucose and insulin response,[4] especially in those that can be absorbed relative fast from the small intestine[5] Foods containing carbohydrates, along with their glycemic responses, have been classified into a glycemic index (GI). The GI of a food is defined as the glucose response two hours after consuming 50-g carbohydrate from the specific test food. GI tables are available that list many types of foods with their GIs.[6] A food is considered to have a low GI if it is ≤ 55, and high GI if ≥70; mid-range GI is 56-69. Since the concept of glycemic index was proposed in 1981[6], numerous studies have been undertaken to elucidate the types of foods that may induce lower postprandial glycemia. Interestingly, a recent meta-analysis of randomized clinical studies suggests that a low-GI diet has a moderately positive impact on improving short-term glycemic control in patients with prediabetes or diabetes[7]

Rice (*Oryza sativa* L.) is a basic foodstuff for more than half of the world's population[8] Although rice is typically regarded as a food with a high GI, its GI levels can considerably range from as low as 54 to as high as 121[9] It is well documented that white rice consumption has been related to a higher risk of type 2 diabetes[10] Nevertheless, rice with high amylose content has been found to result in lower blood glucose and insulin response[11-12] since amylose is more difficult to digest than simple sugars such as glucose; thus, it provides a sustained sugar release into blood without an immediate postprandial surge.[13] Thai jasmine rice or Thai Hom Mali (THM) rice, which is the most widely consumed rice variety in Thailand, generally has a low-to-moderate amylose content (approximately 15-20%),[14] resulting in a relatively high GI.

RD43 is a new white rice variety that was developed by crossbreeding between Khao' Jao Hawm Suphan Buri and Suphan Buri 1.[15] RD43 may present consumers with a healthier option of white rice and may be an alternative choice as it was developed to have a high amylose content or chemical properties expected to slow starch digestion and reduce postprandial blood glucose response. However, we were unable to find any data available of its GI or insulin response. Hence, this study aimed to demonstrate the GI values of THM rice versus RD43 rice in healthy participants and illustrate the insulin responses of both after consumption.

Materials and Methods

Preparation of test rice and reference food

The study involved two varieties of commercial rice, THM and RD43 rice, which were both cropped in Thailand. All rice varieties were prepared using the same fashion by an autonomic rice cooker (1.8-L, Sharp KS-ZT18), except for the rice to water ratio which was 1:1 in THM and 1:1.2 in RD43 rice, according to the cooking process advised for each rice variety by CP Food company.

The reference food was powdered dextrose (S.P.S. Pharmaceutical Co., Ltd., Thailand) dissolved in 250 mL of water. The reference food was consumed after the test foods. To reduce carry-over effects, the two types of rice were consumed first as the test foods with at least a 1-week gap between measurements. Each test meal provided 50 g of available carbohydrates, corresponding to approximately 150 g of cooked rice. In order to prevent the consequence of starch degradation, all the tested rice types were freshly cooked and served to the participants together with 100 mL of clear soup, which contained negligible amounts of carbohydrates, protein, and fat to ensure it did not act as a confounding factor affecting postprandial blood glucose levels, and 150 mL of water. The proximate composition analysis of rice samples and total dietary fiber had been previously analyzed using the Association of Official Analytical Chemists (AOAC) method.

Participants

Healthy people, aged between 18-45 years, were recruited at Thammasat University Hospital, Thammasat University from April to May 2020. Inclusion criteria were men or non-pregnant women who had fasting blood glucose < 100 mg/dL, HbA1c < 5.7%, and body mass index (BMI) between 18.5-22.9 kg/m^2. People who smoked or took medications affecting glucose metabolism were excluded. Each participant provided their informed consent prior to inclusion. The study protocol was approved by the Human Research Ethics Committee of Thammasat University No 1 (MTU-EC-IM-4-139/62), which conforms to the Helsinki Declaration.

A single-sequence, open-label, 3-period, crossover study was conducted. The day before the study, the subjects were informed to consume standard meals with similar serving sizes and composition. Food records were employed to ensure that participants did not consume excessive carbohydrates or foods that could influence the glycemic response prior to the test day. They were also advised to refrain from vigorous exercise, alcohol, and caffeine intake, and to maintain their usual lifestyle habits throughout the study period. Each participant was provided the subject protocol on three different occasions in the morning after 10-12 hours overnight fast. Fasting plasma glucose (FPG) readings were collected at -10 and 0 min prior to the consumption of food, with the baseline value taken as the average of these two values. Participants consumed cooked rice within 10 min (the first bite was considered as 0 minute) and venous blood samples were collected from the antecubital vein, which was cannulated and maintained throughout the entire test period. Blood samples were collected at the intervals of 15, 30, 45, 60, 90, and 120 min after food intake. All participants remained in a supine position during each session. Collected blood samples were immediately handled under standardized conditions, with plasma separated by centrifugation and stored appropriately until analysis.

Biochemical measures

Measurements of blood glucose and insulin were performed by using enzymatic and immunoassay method, respectively. The A1C test was performed on using the certified National Glycohemoglobin Standardization Program (NGSP).

Statistical analysis

To achieve sufficient statistical power for GI testing, a minimum of ten participants were recommended by ISO26642 standard.[16] Moreover, based on a previous research on GI and postprandial glycemic response,[17] a total of six participants were determined to yield 95% confidence level and 90% power. This indicates that a sufficient number of participants were enrolled in this study.

Data were displayed as means ± SD. According to the FAO/WHO 1998, the GI values of the rice were determined as the incremental area under the curve (IAUC) of a portion of test food containing 50 g carbohydrate, expressed as a percentage of the response to the same amount of carbohydrate from a reference food consumed by the same person. The final GI value of each test foods was calculated by averaging the GI values of east test food from each participant. According to the standard protocol,[16] participants having GI value that were more than two SDs outside of the mean were excluded. The IAUC for each food was calculated using the GraphPad Prism 5.0 (GraphPad Software Inc., San Diego, CA, USA). The glycemic and insulin responses were computed geometrically as the mean IAUC following the test food alone, omitting the area below the fasting blood level.[18] The maximal increase in plasma glucose (MIPG) was the postprandial blood glucose after subtracting FPG.[18] All statistical analyses except IAUC and GI were performed with STATA v15.0 with a *p*-value < 0.05 being considered significant. Data were reported as changes from baseline and compared by paired analysis.

Results

Participants

Sixteen healthy people, aged between 23.4-35.9 years, were completed the study. After subjects with GI values that fell outside the range of mean ± 2SD were excluded, data from the remaining 11 participants were included for analysis. Subjects consumed caffeine on the day prior to the study and subjects with GI values that fell outside the range of mean

± 2SD were excluded from the analysis. Table 1 shows baseline characteristics, including mean age of 29.5 ± 3.9 years and normal values for BMI, FPG and A1c.

Table 1 Baseline characteristics of study subjects

Characteristics	Value (n=11)
Age (years)	30.9 (3.2)
BMI (kg/m^2)	21.0 (1.3)
Fasting plasma glucose (mg/dL)	82.8 (3.2)
Fasting insulin (pmol/L)	6.5 (3.8)
A1C (%)	5.2 ± 0.2

Data are presented as mean (SD); BMI, body mass index

Table 2 Plasma glucose, and plasma insulin levels after the consumption of test food.

	RD43 rice	THM rice	Glucose
Plasma glucose (mg/dL)			
0 min	82.8 (3.2)	82.3 (3.0)	83.4 (4.1)
15 min	84.7 (7.1)	93.1 (11.0)*	104.0 (19.5)**
30 min	112.0 (10.9)**	123.1 (17.3)**	135.3 (20.6)**
45 min	117.5 (12.9)**	126.4 (16.0)**	150.4 (26.3)**
60 min	112.5 (18.1)**	119.5 (22.7)**	148.6 (29.8)**
90 min	106.5 (20.8)**	120.9 (24.6)**	115.7 (28.2)**
120 min	108.5 (13.6)**	112.7 (16.4)**	109.1 (18.0)**
Plasma insulin (mIU/L)			
0 min	6.5 (3.8)	7.9 (4.0)	6.3 (3.0)
30 min	36.6 (22.4)**	48.8 (25.2)**	54.8 (19.0)**
60 min	32.5 (17.5)**	39.6 (16.2)**	76.6 (33.7)**
120 min	32.4 (17.9)**	36.8 (17.5)**	33.4 (14.9)**

Data are presented as mean (SD). Statistical significance when compared to the baseline *, p=0.05; **, p<0.01); GLU, glucose, THM, Thai Hom Mali rice

Postprandial glucose response

Table 2 illustrates that consumption of both RD43 and THM rice led to an increase in postprandial glucose concentration after consumption at 30 min and remained high throughout the 120 min of the experiment. The peak concentration of postprandial glucose for the RD43 group was reached at 45 min, which was similar to the THM group and the reference group. However, the significant rise of glucose occurred at 30 minutes following consumption of RD43 rice and THM rice, which was slower than in the reference food which attenuated the increase in plasma glucose 15 minutes after consumption. The IAUCs for postprandial glucose of both kinds of rice are illustrated in Figure 1A. RD43 group resulted in a 28.8% lower glycemic AUC response than THM rice (p < 0.01).

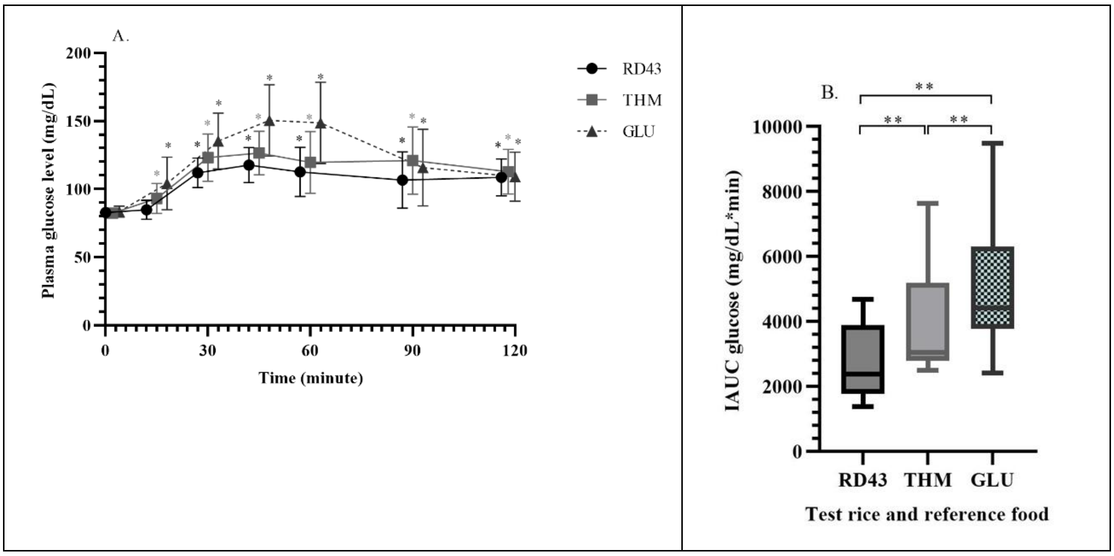

Figure 1 Mean plasma glucose after the consumption of test rice and reference food. **Figure 1A** illustrates mean plasma glucose at each time point. *Statistical significance when compared to the baseline (*p*<0.05). **Figure 1B** illustrates the mean incremental area under curves of plasma glucose. ** Statistical significance when compared between groups (*p*<0.01). GLU, glucose; THM, Thai Hom Mali rice.

Postprandial insulin response

Plasma insulin changes after the consumption of THM rice, RD43 rice, and the reference food are shown in Table 2 and Figure 3. The peak concentrations in postprandial insulin of both groups were reached at 30 min after ingestion whereas the peak insulin concentration in the reference group was reached at 60 min. Consumption of both groups attenuated the increase in postprandial insulin concentration throughout the 120-min experiment (Figure 2A). At 30 min after consumption, the postprandial plasma insulin level of the RD43 group was lower than that of THM rice. The IAUCs for postprandial insulin of both types of rice are illustrated in Figure 2B. RD43 group resulted in a 19.1% lower glycemic AUC response than THM rice (p=0.19). The difference between RD43 rice and THM rice is statistically irrelevant, but the difference between each rice and the reference food is statistically significant (*p* < 0.01) (Table 3).

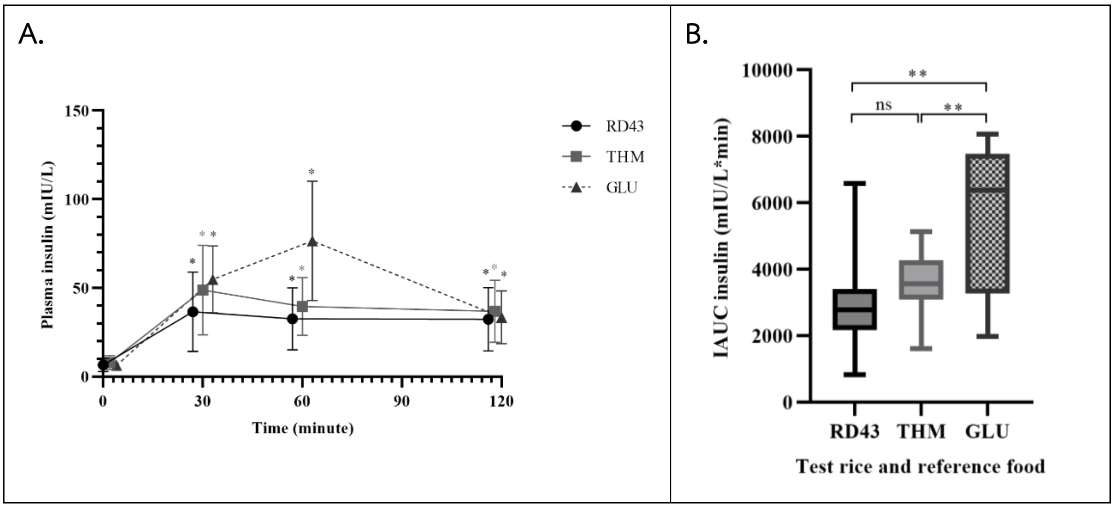

Figure 2 Mean plasma insulin after the consumption of test rice and reference food. **Figure 2A** illustrates mean plasma insulin at each time point. *Statistical significance when compared to the baseline (*p*<0.05). **Figure 2B** illustrates the mean incremental area under curves of plasma insulin. **Statistical significance when compared between groups (*p*<0.01). GLU, glucose; ns, not significant; THM, Thai Hom Mali rice.

Glycemic indices

As shown in Table 3, according to GI value classification,[19] RD43 and THM rice are defined as having low-to-medium and high GI value, respectively. The mean GI value for RD43 rice was 56.9 ± 11.3 (ranging from 45.6 to 68.2), which places it within the low-to-medium GI category, whilst the mean GI value for THM rice was 80.1 ± 15.8; this showed significant difference (*p*<0.01).

Table 3 Incremental area under curves of plasma glucose and plasma insulin, and glycaemic indices of test food.

	RD43 rice	THM rice	Glucose	*p*-value
IAUC glucose (mg/dL*min)	2770.1 (1193.1)	3887.4 (1732.3)	4940.9 (2177.3)	RD43 vs THM *p*<0.01
IAUC insulin (mIU/L*min)	2852.3 (1524.9)	3525.5 (1084.9)	5433.6 (2188.9)	RD43 vs THM *p*=0.19
Glycaemic index	56.9 (11.3)	80.1 (15.8)	-	<0.01

Data are presented as mean (SD); GLU, glucose, THM, Thai Hom Mali rice.

Discussion

In this study, we investigated the GI values of two varieties of white rice including THM rice, a traditional white rice, and RD43 rice, a novel variety. As shown in Table 3, according to the classification of GI value[19], RD43 rice was categorized as low-to-medium GI, whilst THM rice was rated as high GI. The mean GI value for THM rice (GI = 80.1) was significantly higher than that of RD43 rice (GI = 56.9) (*p*<0.01). GI of THM rice in the present study was similar to previous reports at 72-116.[20] The low-to-medium GI of RD43 rice is possibly ascribable to high content of amylose resulting in difficult and slower digestion. This could be due to the intestinal amylase enzyme, which has less effect on rice with high amylose content, thus slowly increasing the plasma glucose after rice digestion.[21] Low glycemic index has been shown to have beneficial effects, including lower postprandial glucose and insulin responses, possibly improved insulin sensitivity and glycemic control.[22]

In our study, plasma glucose and insulin levels were lower following RD43 rice consumption, as compared to THM rice (Figure 1 and 2). Our results were similar to previous studies conducted in healthy adults which demonstrated that low glycemic index is a good predictor of postprandial glucose and insulin response.[23] Undoubtedly, many T2DM research demonstrated that a low-GI diet elicited a significantly lower postprandial glycemic response, as opposed to a high-GI diet,[24-26] and postprandial hyperglycemia appears to play a crucial role in the pathophysiology of chronic diabetic complications. Although data on postprandial glucose levels after ingestion of rice in normal healthy adults is limited, the findings of this study confirm the evidence of better glucose and insulin responses in lower GI diets. The findings from our study are consistent with a prior cross-over study that examined the effect of using 30% RD43 rice flour instead of wheat flour in normal subjects and reported that the incremental change in postprandial glucose after consuming 30% RD43 rice noodles was lower than the wheat-based control group.[27] In vitro results also illustrated the reduction in starch digestibility, the hydrolysis index, and rapid digestible starch (RDS) supporting its impact on glycemic response. Generally, the homeostasis of postprandial plasma glucose is controlled not only by the direct stimulation of insulin secretion for absorption of nutrients but also through the secretion of incretin hormone.[28] A glucagon- like peptide-1 (GLP-1) is an incretin hormone released by enteroendocrine L- cells predominantly in the ileum and colon in response to food intake. It is thought that dietary fiber and indigestible starch, which could lengthen the gastric emptying time, will enhance the effects of prolonged stimulation of GLP-1 release.[27] The postprandial glucose levels are then decreased as GLP-1 concentration rises in response to lower GI food. However, the measurement of GLP-1 was not included in this study.

Comparison with other Thai rice varieties further contextualizes RD43's metabolic relevance. Conventional white rice and glutinous rice typically have GI values of 87-89, considerably higher than RD43. THM rice, the most popular variety in Thailand, generally has lower amylose content, contributing to higher digestibility and GI. Glutinous rice, with minimal amylose, undergoes rapid starch digestion and exhibits the highest GI among Thai rice types.[14,29] In contrast, RD43 rice was specifically bred to have higher amylose and increased levels of resistant and indigestible starch, which slow gastric emptying and glucose absorption. This chemical profile aligns RD43 with dietary strategies aimed at reducing postprandial glycemic impact in the traditional Thai diet.

To the best of our knowledge, this is the first in vivo study assessing the GI, as well as postprandial glucose and insulin responses of RD43 rice. However, our study has some limitations. First, since this study primarily aimed to determine the GI, incretin-related parameters were not included in the analysis, which may have provided additional insights into the mechanisms underlying glycemic regulation. Second, the frequency and timing of blood sampling were constrained, and as a result, the true peak glucose response may not have been fully captured, unlike what could be achieved with continuous glucose monitoring. Future studies are therefore recommended to employ continuous glucose monitoring systems or longer intervention periods to A postprandial rise in plasma glucose was significantly less following the consumption of RD43 rice than THM rice, while the insulin level showed a tendency to be lower, though not statistically significant. These findings suggest that consumption of RD43 rice was more effective at reducing postprandial glucose than THM rice. Therefore, RD43 rice can be used as an alternative rice in order to manage postprandial glycemia in healthy subjects. Further study is needed to determine the long-term effects of RD43 rice.

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