Original paper

White Rice Glycemic Index Measured in Venous and Capillary Blood Samples

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This study was to examine the effects of certain methodologic choices for testing glycemic index (GI), incremental area under curve (IAUC), and blood glucose responses in 12 healthy adults, who were fed white rice, rice porridge, and overnight rice. Blood samples were collected from venous plasma (VP), capillary plasma (CP), and capillary blood (CB). The results showed the mean GI value (VP; 87 ± 2.5 , CP; 85 ± 2.5 , and CB; 84 ± 2.6); the mean IAUC (CB; 5006 ± 292 , CP; 4844 ± 287 , VP; 3784 ± 221); the mean postprandial glucose response (CB; 118.2 ± 3.3 , CP; 115.2 ± 3.2 , VP; 90.7 ± 2.4); Significant correlation was observed between three sampling methods ($p < 0.01$). In conclusion, the VP sampling approach had a lower degree of dispersion and a higher stability that is a more effective methods to determine GI, IAUC and blood glucose responses. and rice porridge produced the highest GI, followed by white rice and overnight rice.

Keywords: glycemic index, white rice, rice porridge, overnight rice, venous and capillary blood

Introduction

Rice is a critical crop because it is a major food staple of many people worldwide. The glycemic index (GI) of white rice is influenced by many factors including the amylose content (Sagum and Arcot, 2000; Frei *et al.*, 2003; Fitzgerald *et al.*, 2011); cooking method (Frei *et al.*, 2003); grain size (Snow and O'Dea, 1981); physical characteristics, such as gelatinization and retrogradation (Chung *et al.*, 2006; Panlasigui *et al.*, 1991); amylose-to-amylopectin ratio (Juliano and Goddard, 1986); and amylolytic enzyme sensitivity (Jenkins *et al.*, 1982). Many rice varieties have been classified as high-GI foods, and this is notable because the long-term consumption of high-GI foods increases the risk of obesity, type 2 diabetes, and diabetes-related complications (Pi-Sunyer, 2002; Wolever, 2006; Livesey 2008). Epidemic studies have also shown that dietary GI and high-density lipoprotein cholesterol correlate negatively (Livesey, 2008; Amano, 2004). Clinical studies have revealed that a low-GI diet can improve insulin sensitivity and reduce lipids and glucose in the blood (Price, 2006; Willett, 2002; Slyper, 2005; Philippou, 2008). Therefore, postprandial blood glucose responses and the GI of foods are

critical health information.

The GI is a numerical scale used to indicate how fast and how high a particular food raises blood glucose levels. The ranking from 1 to 100, foods can be classified as low GI foods (≤ 55), medium GI foods (56 – 69), and high GI foods (≥ 70). The standard method for measuring the GI is feeding a portion of the food containing 50 grams of digestible (available) carbohydrate and then measuring their blood glucose levels within 2 h of consuming the food, the incremental area under their blood glucose response curve (IAUC) for test food is then measured. The GI value for the test food was the ratio of test food IAUC to standard glucose IAUC, multiplied by 100. (Brand-Miller, 2003a).

Postprandial blood glucose is influenced by numerous factors. Accurate blood glucose concentration measurements are crucial for detecting diabetes in a timely manner and preventing it from progressing. Clinically, venous plasma (VP) glucose is used for blood glucose monitoring, and the World Health Organization (WHO) has stipulated that the diabetes diagnosis criteria should be based on VP glucose (Sacks, 2002). Technological advancements over the years have improved not only the accuracy and precision

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Table 1. Test food preparation methods

Test food	White rice	Rice porridge	Overnight rice
Japonica rice (Kaohsiung 145)	1. Take 62.5 g of raw white rice	1. Take 107 g of cooked rice	1. Take 107 g of cooked rice
	2. Add 62.5 mL of water	2. Add 220 mL of water	2. Cool the rice and then place it in a refrigerator for 22–24 h
	3. Steam the rice for 40 min and keep insulated for 10 min	3. The rice was cooked for 25 min	3. Remove the rice from the refrigerator and reheat it for 5 min with an electric steamer
	4. Yield: 107 g of steamed white rice	4. Yield: 290g of rice porridge	4. Yield: 107 g of reheated overnight rice

of self-monitoring blood glucose (SMBG) devices, but also their convenience and affordability. In addition, SMBG devices can now provide real-time results. All these improvements have contributed to the increased prevalence of SMBG devices, which can be employed for various purposes, including verifying food GI (Sacks, 2002; Anderson, 2002; Batra, 1994).

In fact, both fingerstick blood sampling and venous blood sampling (FAO/WHO, 1997) are considered acceptable by the Food and Agriculture Organization (FAO) of the United Nations and WHO. Nonetheless, the blood sampled by a SMBG device is usually capillary blood (CB), which contains both arterial and venous blood; consequently, a discrepancy exists between CB and VP in the blood glucose concentration (Jenkins, 1981; Ludwig, 2002). Therefore, Some research laboratories (Wolever *et al.*, 2003) have developed methods for using capillary plasma (CP) to study the digestion and absorption of carbohydrates to measure the GI of foods.

This study used CB, CP, and VP samples to examine the effect of three different cooking methods with rice (white rice, rice porridge, and overnight rice) on postprandial blood glucose responses, the IAUC, and the GI. The study results may be useful for individuals seeking to reduce their high GI food intake by adopting a healthier method for cooking white rice.

Materials and Methods

Subjects Twelve healthy adults of East Asian descent (5 women and 7 men) were recruited from National Pingtung University of Science and Technology. The participants were weight-stable and not on any medication during the study period. All participants had normal fasting blood glucose concentrations and were asked to restrict their intake of alcohol, beans/legumes, and fried foods, and to refrain from unusual eating habits and physical activities before each test day (Brand-Miller, 2004; Lin *et al.*, 2010). The mean age ($\pm$ SEM) of the participants was 20 ± 1 years (range, 18–26). The mean body mass index was 22.0 ± 0.4 kg/m² (range, 20.0–24.0), the mean weight was 67.8 ± 1.1 kg (range, 49.0–75.0), and the mean height was 174.4 ± 1.8 cm (range, 147.0–183.0). The average fasting VP glucose was 74.0 ± 0.6 mg/dL (range, 69.5–76.5). This research project is in full compliance with the Declaration of Helsinki and has stated all foreseeable risks

and stress that the study subjects may be exposed to. Before the inclusion of the subjects, We obtained informed consent from the study subjects and ensured that they fully understood the objectives, methods, procedure, and any possible conflicts of interests involved in this research project. We also submitted this information to the Research Ethics Committee (International Review Board) for review and evaluation, and the committee provided guidance and approved this research project. This study was approved by the Ethics Committee of Pingtung Christian Hospital.

Test foods The test foods were made from white rice and the reference food was glucose. The white rice variety used in this study was Kaohsiung 145, which was purchased from a white rice factory (Pingtung Sin Fang, Taiwan). The composition of the rice is as follows: total milled rice (82.68%), head rice (73.8%), white center (0.17), white back (0.00), white belly (0.15), crude protein (6.02%), amylose (19.8%), overall palatability (0.159), calories (354 kcal/100 g), crude fat (0.7 g/100 g), crude protein (7.0 g/100 g), total carbohydrate (80.0 g/100 g), and sodium (10 mg/100 g). The chemical composition of the test food was analyzed using the standard method described in AOAC 46-11 (2000). First, all the collected samples were dried to constant weight. The protein content was assessed through the quantitative analysis of nitrogen. The Kjeldahl method was employed to determine the total nitrogen content, and which was multiplied by the nitrogen coefficient of the sample (6.25) to determine the crude protein content. The fats were measured gravimetrically, diethyl ether and petroleum ether were added as extractants. For bound lipids, these lipids must undergo acid treatment followed by hydrolysis before fat extraction (AOAC, 1995). Free sugars (i.e., glucose, fructose, maltose, maltotriose, and sucrose) were measured using an ion chromatograph system (Dionex, Sunnyvale, CA). Enzymatically available starch content was analyzed using the method of McCleary *et al.* (1994) and an assay kit (Megazyme, Bray, Ireland). The available carbohydrates were calculated as the sum of free sugars and enzymatically available starch. Table 1 lists the cooking methods for the white rice, rice porridge, and overnight rice. Glucose was used as a reference food for the GI test. All test meals contained 50 g of available carbohydrates, wherein the amount of available carbohydrates was equal to total carbohydrates in food

minus the value of dietary fiber. Each subject was asked to consume glucose three times at the beginning, middle, and end of study to reduce the effect of day-to-day variation in glucose tolerance (Brand-Miller, 2004). This procedure was followed in strict compliance with the protocol recommendations described in the ISO guidelines (ISO/FDIS 26642:2010).

Experimental procedures The subjects fasted for 10–12 h overnight and performed the test at 8 AM in lab. Each subject was randomly fed the equivalent of 50 g of available carbohydrates of the test foods or reference food (220 mL of water was also served). Blood samples were taken before the subjects ate (at 0 min) and at 15, 30, 45, 60, 90, and 120 min after the meal. (Moghaddam *et al.*, 2006; Brand-Miller *et al.*, 2004; Lin *et al.*, 2010). Blood samples were collected as follows: a researcher withdrew blood (1.5 mL) intravenously by inserting a scalp needle into the subjects' forearms. When the blood samples were taken, the outer tube was filled with normal saline (0.9%) to prevent the scalp needle from clotting. For CB and CP, the subjects' hands were first soaked in warm water ($\pm 40^{\circ}\text{C}$) for 3–5 min to accelerate blood circulation. Fingerstick CB glucose (4 μL) was collected using an automatic lancet device (Safe-T-Pro; Roche Diagnostics GmbH, Mannheim, Germany) and drop on strip and measured with an Accu-Chek Advantage glucose meter (AGM) (Roche Diagnostics, Indianapolis, IN). Milking finger pulp was used to withdraw CP (1.5 mL) from the subjects.

The collected blood samples for CP and VP were placed in heparinized tubes and centrifuged for 3 min at $12\,500 \times g$ at 4°C to separate the plasma. The plasma was subjected to a principal analysis (glucose oxidase and peroxidase) by using a biochemical analyzer (Model YSI 7100; Multiparameter Bioanalytical System, Yellow Springs, USA) to determine the blood glucose concentration. Peak rise was the maximum glucose concentration achieved minus fasting glucose. The trapezoidal rule, the IAUC method for determining the blood glucose response curve (ignoring the area beneath the fasting concentration), was used to calculate the GI values. The GI value for the test food was the ratio of test food IAUC to the standard glucose IAUC, multiplied by 100.

Statistical analysis The data obtained were first calculated using Microsoft Office Excel 2003 (Microsoft Corporation, Redmond, WA) and is presented as the mean $\pm$ standard error of the mean (SEM). All figures were produced using SigmaPlot Version 12.5 (Systat Software Inc., San Jose, CA, USA). One-way analysis of variance (ANOVA) with Tukey's post hoc test was used at each time point for each sample to observe the difference in the samples versus the control (white rice). One-way ANOVA with Tukey's post hoc test was performed to observe the difference among the groups. All ANOVA tests were performed using SPSS version 21.0 (IBM Corp., Armonk, NY, USA).

Results

Postprandial glucose responses Figure 1 shows the glucose

responses elicited by the three test foods and reference food, which were measured using three methods (VP, CP, and CB). The mean VP glucose concentration tended to have the lowest responses curve at every time point in all test foods, whereas CB showed highest response curve among the three methods. The figure also shows the postprandial blood glucose responses in VP, CP, and CB of healthy adults after ingesting glucose, white rice, rice porridge, and overnight rice. For glucose ingestion, the peak blood glucose concentration in VP, CP, and CB was reached at 30 min (Figure 1A). The blood glucose concentration in VP, CP, and CB peaked at 45 min for white rice (Figure 1B), 30 min for rice porridge (Figure 1C), and 45 min for overnight rice (Figure 1D). The postprandial blood glucose concentration in VP was significantly lower than that in CP and CB at each time point ($p < 0.05$). Postprandial VP glucose also found less fluctuating compared to CP and CB. Moreover, no significant difference in postprandial blood glucose concentration was observed between CP and CB ($p > 0.05$).

Figure 2 shows scatter plots of all the results for each test food and analysis method. Regarding the correlation analysis, the ANOVA results in Figure 2 depict the differences in the glucose concentrations. The strongest correlation (R^2) was between CP and CB ($R^2 = 0.995$), whereas that between CB and VP was 0.905. The smallest correlation was between VP and CP ($R^2 = 0.886$). All correlations were significant ($p < 0.01$), as determined through a two-tailed Pearson's correlation test. This not only implies that the data for all three blood sampling methods are significantly correlated, but the three test foods (i.e., white rice, rice porridge, overnight rice) and reference food (i.e., glucose) also showed significant differences among the three methods. The mean $\pm$ SEM glucose concentrations (test food and reference glucose) revealed that CB had the highest glucose concentration, followed by CP, and then VP (Table 2). The coefficients of variation (CVs) of all the test foods were lower in VP than in CP and CB; the corresponding CVs are shown in Table 2. Comparing the difference between after ingestion of glucose concentrations based on VP, CP and CB at different time points (Table 3) revealed that the maximum difference between VP and CB (44.8%) was at 30 min, and that between VP and CP (42.4%) was at 30 min. The lowest mean differences were between CP and CB at 0 min (1.8%), 90 min (2.3%), and 30 min (2.4%).

IAUC Table 4 shows the IAUC of all the test foods, as determined by the VP, CP and CB measurements; specifically, the table shows the mean IAUC for white rice, rice porridge, overnight rice, and glucose. A value of $P < 0.05$ was considered significant. However, the VP measurements were significantly lower than the CP and CB measurements.

Glycemic index The mean GI was calculated for each test food and each method, the results of which are shown in Figure 3. On average, the mean GI of rice porridge (VP; 101.8 ± 5.2 , CP; 98.4 ± 8.1 , and CB; 97.6 ± 8.5) was highest compared to those of white rice and overnight rice; the mean GI of overnight rice (VP;

Fig. 1. Postprandial blood glucose responses in VP, CP, and CB of healthy adults after ingesting (A) glucose, (B) white rice, (C) rice porridge, and (D) overnight rice. Values (mean $\pm$ SEM, $n = 12$) marked with an asterisk differ significantly from the other groups at each time point (one-way ANOVA, Tukey's post hoc, $p < 0.05$). Closed circle, VP; open circle, CP; closed inverted triangle, CB.

VP, venous plasma; CP, capillary plasma; CB, capillary blood.

Fig. 2. Comparison of the glucose concentrations for VP versus CP ($R^2 = 0.886$, $p < 0.01$), VP versus CB ($R^2 = 0.905$, $p < 0.01$), and CP versus CB ($R^2 = 0.995$, $p < 0.01$).

VP, venous plasma; CP, capillary plasma; CB, capillary blood.

91.9 ± 3.7 , CP; 90.6 ± 6.6 , and CB; 89.8 ± 7.2) was lowest compared to those of white rice and rice porridge; the mean GI of white rice (VP; 93.8 ± 3.7 , CP; 91.1 ± 6.8 , and CB; 90.6 ± 7.5). Overall, the highest mean GI of all the test foods was in VP (95.8 ± 1.5), followed by CP (93.3 ± 1.2), and then CB (92.6 ± 1.2).

Among the three methods, VP, CP and CB gave significantly different mean GI values ($p < 0.05$); but there are no significant difference between capillary plasma and blood ($p > 0.05$). Regarding the mean GI values among the three test foods, All three methods indicated that the rice porridge had the highest GI,

Table 2. Glucose concentrations of the test foods and glucose as determined by VP, CP and CB

	Glucose concentration (mg/dL)							
	White rice	CV(%)	Rice porridge	CV(%)	Overnight rice	CV(%)	Glucose	CV(%)
VP	89.1±3.7 ^b	14.6	98.5±5.2 ^b	18.5	89.5±3.7 ^b	14.6	93.4±4.9 ^b	18.4
CP	114±6.8 ^a	20.9	121.6±8.1 ^a	25.1	111.3±6.6 ^a	20.7	119.6±7.6 ^a	22.3
CB	116±7.5 ^a	22.4	121.2±8.5 ^a	24.5	114.6±7.2 ^a	21.8	124.4±7.9 ^a	22.2

^{a-b}Value (mean±SEM) with different letter indicate significant differences as determined by one-way ANOVA with Tukey's post hoc ($p < 0.05$).

VP, venous plasma; CP, capillary plasma; CB, capillary blood.

Table 3. Differences between after ingestion of glucose concentrations based on VP, CP and CB at different time points

Time	0	15	30	45	60	90	120
VP	74±0.6	101.8±2.3	110.6±3.3	110.3±4.1	103.0±4.5	84.6±3.5	69.4±3.2
CP	82.4±1.3	129.6±5.1	153.0±5.2	142.6±5.5	128.7±4.4	112.5±5.7	88.2±4.3
CB	84.2±3.8	136.2±5.6	155.5±5.6	150.9±5.7	135.3±5.1	114.9±7.1	93.5±7.2
different VP and CP (%)	8.4 ^a	27.8 ^{ab}	42.4 ^{ab}	32.3 ^{ab}	25.7 ^{ab}	27.9 ^{ab}	18.8 ^{ab}
different VP and CB (%)	10.2 ^a	34.4 ^a	44.8 ^a	40.5 ^a	32.3 ^a	30.3 ^a	24.1 ^a
different CP and CB (%)	1.8 ^b	6.6 ^b	2.4 ^b	8.2 ^b	6.5 ^b	2.3 ^b	5.3 ^b

^{a-b}Value (mean±SEM) with different letter indicate significant differences as determined by one-way ANOVA with Tukey's post hoc ($p < 0.05$).

VP, venous plasma; CP, capillary plasma; CB, capillary blood.

Table 4. IAUC of the test foods and glucose, as determined by the VP, CP, and CB measurements

	Incremental area under the curve							
	White rice	CV(%)	Rice porridge	CV(%)	Overnight rice	CV(%)	Glucose	CV(%)
VP	2266±298 ^b	57.4	2601±278 ^b	48.2	2115±218 ^b	42	2414±313 ^b	57.6
CP	4315±298 ^a	44.1	4992±272 ^a	37.2	4020±202 ^a	31.3	4705±314 ^a	44.6
CB	4598±289 ^a	42.1	5371±249 ^a	34	4298±155 ^a	23.2	5057±307 ^a	42.1

^{a-b}Value (mean±SEM) with different letter indicate significant differences as determined by one-way ANOVA with Tukey's post hoc ($p < 0.05$).

VP, venous plasma; CP, capillary plasma; CB, capillary blood.

Fig. 3. Glycemic index of three test foods (white rice, Rice porridge and overnight rice) as determined by VP, CP and CB. Values (mean ± SEM, $n = 12$) with different letters are significantly different (one-way ANOVA, Tukey's post hoc, $p < 0.05$). Closed square, VP; light gray square, CP; gray square, CB.

VP, venous plasma; CP, capillary plasma; CB, capillary blood.

followed by white rice, and then overnight rice; however, they all had a high GI ranking, and CP and CB showed similar GIs.

Discussion

The main purpose of this study was to examine the effects of certain methodologic choices for testing GI, IAUC, and postprandial blood glucose responses. Our results show that, compared with the CP and CB samples, the VP samples exhibited the lowest glucose concentrations and IAUCs and the highest GIs. Moreover, it was found that VP, CP, and CB were significantly intercorrelated, and the GI for the test foods was in the order of rice porridge > white rice > overnight rice. For all test foods, their CVs was lower in the VP samples than in the other samples, indicating that the VP sampling approach had a lower degree of dispersion and a higher stability. Under the fasting condition, we observed no significant difference between the blood glucose concentrations in the VP, CP, and CB samples. However, 2-hour postprandial tests revealed significant differences in the mean maximum difference between VP and CB (30.9%) and the mean minimum difference

between CP and CB (4.7%). This significant difference in blood glucose concentrations between venous blood and capillary blood has been demonstrated in many studies (Yang, 2012; Katja, 2006; Hatonen, 2006; Wolever, 2004; Sandbaek, 2003). Some of these studies have even reported discrepancies greater than 50%. The discrepancy between venous blood and capillary blood may be attributable to many factors, particularly that absorbed glucose is first transported through the arteries and then diffused into tissue cells for metabolism via peripheral capillaries, whereas glucose, partially consumed then transported into the veins. Consequently, it is reasonable for the arterial blood glucose concentrations to be higher than venous blood glucose concentrations and for glucose concentrations in capillary to approximate that in arterial blood. Similarly, it is reasonable that the postprandial capillary glucose concentration should be higher than the venous glucose concentration (Yang, 2012; Burtis, 1994).

Second, the insulin sensitivity of peripheral capillaries should be considered. For example, the epidermal layer of the skin is more metabolically active after intense workouts (Ryan, 1983), and the metabolic activity of skeletal muscle blood flow can increase 20-fold (Guyton, 2000). The fact that workouts can enhance the insulin sensitivity of peripheral capillaries is particularly significant for diabetic patients because they tend to have poor peripheral insulin sensitivity (Marks, 1996; Haecckel, 2004). Finally, the time and site of blood sampling also affect the results (Marks, 1996). To avoid delayed blood glucose responses, blood sampling of the three types of blood in this study was completed within 3 min on average. In addition, the study participants avoided intense physical activity and alcoholic beverages and to maintain their regular eating habits (Brouns, 2005), even though Campbell *et al.* (2003) argued that these factors have a negligible effect on GI.

For the GI measurements, CP and CB from a fingerstick is a common blood sample collection method used in postprandial glucose measurements. However, in this study, VP showed higher values than CP and CB from a fingerstick did, and specificity for body glucose measurements (Guyton and Hall, 1996). Some studies have demonstrated that, in a laboratory setting, GI values derived from VP measurements have confidence intervals greater than 50%, whereas those derived from CP and CB measurements have confidence intervals less than 30%. Compared with blood glucose concentrations in VP, those in CP and CB are higher; moreover, compared with VP, CP and CB are more responsive to blood glucose fluctuations (Hatonen, 2006; Wolever, 2004).

In the present study, rice porridge produced the highest mean GI and mean IAUC (99.3 ± 0.6 and 4008.6 ± 390 , respectively), followed by steamed rice (92.1 ± 0.4 and 3710 ± 363 , respectively), and then overnight rice (90.7 ± 0.4 and 3677 ± 366 , respectively). Furthermore, fluctuations in blood glucose from eating rice porridge were more accentuated than those from eating steamed rice or overnight rice. This shows that the speed of blood glucose absorption and digestion depends on the cooking method used

(Chung *et al.*, 2006; Panlasigui *et al.*, 1991). The most crucial component of white rice is starch, which is composed of amylose and amylopectin, the characteristics of which have been extensively studied (Noda, 2008; Chung, 2011; Li, 2008a; Wang, 2010). The structure and form of starch determine the enzyme sensitivity. For amylose, because it has fewer points for amylase to act upon, lower water content, and tightly enlaced branches, the digestion and absorption of amylose is slow and incomplete. By contrast, amylopectin is more readily hydrolyzed (i.e., it can be digested and absorbed more quickly) and, because of the substantial rise in blood glucose, amylopectin has a higher GI (Yoon, 1983). Gelatinization is the structural change that starch undergoes when mixed with water and exposed to a high temperature, and gelatinized starch has a higher GI than ungelatinized starch (Kohyama *et al.*, 2004; Sagum and Arcot, 2000). The type of white rice examined in the present study was japonica rice, which has an amylose content of 19.8%. Aside from knowing that heating with water increase the GI of rice starch, the GI of overnight rice is significantly lower than that of rice porridge because of starch retrogradation from reheating refrigerated rice (Chung *et al.*, 2006; Keetels *et al.*, 1996; Garcia-Alonso *et al.*, 1999). Refrigerating cooked rice alters the molecular structure of the starch, causing rearrangement of the molecules. Moreover, polymerization and recrystallization would also occur between starch chains, and the released amylose molecules link with each other and form an ordered structure that renders the starch more difficult to dissolve, digest, and absorb (Wickramasinghe, 2008; Varavinit, 2003).

The *American Journal of Clinical Nutrition* reported that the GI of rice products ranges from 19 to 95 (Foster-Powell *et al.*, 2002). In addition, in the project of International Rice Research Institute, which analysed the GI of 235 rice varieties from all over the world, the GI of rice was found to be between 48 and 92 (mean, 64). The project also revealed that Swarna rice (India) has a low GI (<55), whereas Doongara rice (Australia) and Basmati rice (India) have a medium-level GI (56–69) (Henna, 2012). David (2008) investigated varieties of rice worldwide and various rice cooking methods and reported a large GI range of 19–109. This suggests that the postprandial blood glucose response is determined by the rice variety and measuring method, whereas the GI is determined by the cooking method.

Different blood samples yield different blood glucose responses; generally, the blood glucose response of CB is greater than that of CP, and the blood glucose response of CP is greater than that of VP, and yet these three types of blood samples are also significantly associated. For clinical diagnosis and monitoring, the blood glucose concentrations obtained from the three blood samples are equally critical. Although no fixed-ratio conversion coefficient is available, the VP glucose concentration is more accurate than the other two for blood glucose monitoring and diabetes diagnosis. The fingerstick blood glucose measuring method is convenient and economical for everyday self-monitoring

of blood glucose. Regarding the food GI measurements, our experimental results show that VP is a more effective approach for obtaining more accurate blood glucose responses because of its lower CV and higher stability.

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