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Effects of Buckwheat, Potato and Rice on Glycemic Indices in Healthy Subjects

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ABSTRACT : We compared the long-term metabolic effects of equal amounts of carbohydrate from potato, rice and buckwheat on glycemic indices and blood lipids in healthy subjects. Nine healthy volunteers-2 men and 7 women were studied. All subjects ate diets based on the same-7-day rotating menu differing only in that the major source of carbohydrate (about 50% of daily total calories) came either from buckwheat, rice or potato. The study was conducted with a triple crossover design over three 7 day periods. On the morning of the 8th day, fasting blood was drawn from each subject to determine serum glucose, insulin, triglycerides, total and HDL-cholesterol. Subjects were then asked to eat breakfast with their respective carbohydrate within a 20 min period. Blood samples were drawn at 30, 60, 120 and 180 min after the start of breakfast to determine glucose and insulin levels. At 30 min the glucose response to the rice meal(7.15mmol/L) and potato meal(6.71mmol/L) were greater than the response to the buckwheat meal(5.855mmol/L) ($P < 0.05$). The mean area under the glucose response to the curve following the rice meal was greater than that following the buckwheat meal($P < 0.05$). The insulin responses to the potato and rice meals at 30 and 60 min were greater than those to the buckwheat meal ($P < 0.05$). The mean area under the serum insulin response curve after the rice meal was greater than of buckwheat. Blood lipids, uric acid and glycosylated hemoglobin were not affected by the three meals. The study shows that the buckwheat meal has more beneficial effects on glycemic indices than either the rice meal or potato meal in healthy subjects.

Key words : Buckwheat, Potato, Rice, Glycemic indices, Healthy subjects.

INTRODUCTION

Plasma glucose and hormonal responses to meals are believed to depend on their intraluminal digestion rate(Thorne et al., 1983; Jelkins et al., 1984). Raw starches high in amylopectin have been shown to be digested in rats more quickly than starches high in amylose(Borchers, 1961; Sandstedt et al., 1962). Goddard et al.,(1984) have shown that a medium grain rice with 14-17% amylose and 83-86% amylopectin had greater plasma and insulin responses than those of a long grain rice with 23-25% amylose and 75-77% amylopectin. Among the 3 grains, sweet rice with no amylose, but 100% amylopectin had the greatest glucose responses.

Recently, we found that the digestion rate was significantly different for buckwheat, white short grain rice, and potatoes. Boiled potato is rapidly digested, cooked buckwheat is the most slowly digested, rice is intermediate between the two foods.

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Noninsulin-dependent diabetes mellitus(NIDDM) is highly prevalent among adults in Korea where short grain rice(high amylopectin) and sweet rice are daily eaten as a staple food(6). Furthermore, NIDDM is most prevalent in Kangwon Province, Korea where boiled potato whose glycemic indices are similar to glucose are also frequently eaten.

Jenkins et al(7) have suggested that slowly digested and absorbed carbohydrates protect susceptible populations from developing the signs and symptoms of diabetes along with hyperlipidemia. Since buckwheat has a slower digestion rate than either rice or potato, we hypothesized that buckwheat would be most beneficial to the prevention of hyperglycemic effects.

Therefore, we compared the long-term metabolic effects of equal amount of carbohydrate from potato, rice and buckwheat on glycemic and blood lipids in healthy subjects consuming a typical Korean diet which are high in carbohydrate, moderately high in protein, and low in fat.

MATERIALS AND METHODS

Subjects

Nine healthy volunteer subjects-2 men and 7 women were selected from the staff of the Korea Nutrition Institute at Hallym University. The mean age was 24.0±4 (18-34) year; weight, 55±2 (51-66) Kg; and height, 159.3±5 (150-172)cm. No subjects ingested any drug known to affect glucose, insulin or lipid metabolism.

Diets

Subjects were instructed about the use of weighing balances, measuring cups and spoons to assist in the accurate reporting consumption of food and beverage amounts. Then, they were asked to record their food intake for three consecutive days. The nutrient intakes were estimated for each subject, and the results were used to estimate caloric and carbohydrate ingestion as well as plan the menu for the study.

The three diets making up the 7 day rotating menu contained natural foods and met the daily Recommended Dietary Allowances(RDA)(8) for all known nutrients. The diets differed only in major carbohydrate sources, i. e. buckwheat, potato or rice. The menu provided 26.5±2 % of total calories from protein, 16.2±2 % from fat, and 57.3±5 % from carbohydrate(Table 1). This is a typical Korean caloric distribution, higher in carbohydrate, moderately higher in protein and lower in fat as compared to the average American diet. The diet contained 13-15 g of fiber. Nutrient compositions of the three grain are compared in Table 2. Approximately, 50% of the total calories was provided by the carbohydrate of rice, potato or buckwheat. For example, if a person consumed 2000 kcal daily, he or she ingested 250g carbohydrates which is equivalent to 1000 kcal from that of rice, potato or buckwheat. To provide the

Table 1. Nutrient intakes of the subjects during the study.

Nutrients	Mean	Range	%
Calories (Kcal)	2060	1888 - 2502	
Protein (g)	137	127 - 146	26.5
Fat (g)	36.7	35 - 39	16.2
Carbohydrate (g)	295.4	254 - 384	57.3
Fiber (g)	14.0	13.0 - 15.0	

Table 2. Nutrient Compositions of Three Grains.

Grain	Weight (g)	Energy (Kcal)	Protein (g)	Fat (g)	Carbohydrate	Fiber (g)
Buckwheat flour (raw)	100	361	12.1	3.1	68.5	1.0
Potato, whole no skin (raw)	400	320	6.0	0.8	74.0	2.0
Rice (raw) 70% polished	100	363	12.3	1.1	78.8	0.3

amounts, 365g of raw buckwheat, 1348 g of raw potato or 317 g of raw rice was needed, respectively. These carbohydrates were equally distributed for breakfast, lunch and dinner. The remaining carbohydrate was provided from other natural foods, but not from concentrated sweets. The menu contained 6 or more servings of various leafy of other vegetables and one serving of fruit daily. This is a common Korean menu pattern.

A short grain rice was boiled in water in a rice cooker for 20 min; peeled potato was steamed approximately 30 min. Buckwheat flour was mixed with water to make pancakes on an ungreased teflon coated pan. Subjects were served breakfast, lunch and dinner at the cafeteria of the University Hospital. Fruit was served as a snack at their offices. Subjects were required to eat all foods served. Dietian supervised the subjects during the intake of the three meals and checked their trays to ensure all foods were consumed. Subjects were not allowed to eat other food or drinks elsewhere.

Experimental protocol

The experimental protocol was approved by the Human Subject Committee, Institutional Review Board, at Hallym University. The study was conducted with a triple crossover design over three 7 day periods. All subjects ate diets based on the same 7 day rotating menu differing only in that the major sources of carbohydrate came either from buckwheat, rice or potato; and the remaining three, buckwheat. The carbohydrate foods were switched every 7 days so that each subject had all three grains.

At the beginning of the study and on the 8th day of each study period, subjects were brought to the University Hospital early in the morning. Overnight fasting blood( ) 12hr) was drawn by venipuncture into two tubes : one contained none for the sera and the other contained EDTA for whole blood. Whole blood was used for glycosylated hemoglobin measurements. All blood samples were kept at 4℃ while sera were separated after centrifugation for 20min at 1500xg. Sera were used to determine glucose, insulin, triglycerides, total cholesterol, HDL-cholesterol, and uric acid.

Immediately after drawing fasting blood, subjects were served for breakfast with their respective carbohydrate foods. The amount and kind of foods served for breakfast were exactly the same except for the carbohydrate foods. The subjects were asked to finish their meals with a 20 min period under the supervision of the principal investigator. Blood sample for glucose and insulin determination were drawn at 30, 60, 120 and 180 min after the beginning of the meal.

Chemical Assays

Serum glucose was determined by the glucose oxidase method(9), and serum insulin levels were measured by radioimmunoassay(10). Total cholesterol, HDL-cholesterol, and triglycerides were determined by the automated enzymatic method(11,12). Glycosylated hemoglobin was determined by calorimetric assay(13). Uric acid was determined by using the Centrifchem System(Baker Instrument Co, Pleasantville, NJ).

Statistical analysis

For each of the responsive variables, mean values were determined, and an estimate of error was calculated with an analysis of variance. Duncans multiple range test was used to determine the significance of the difference among group of values in the study(14).

RESULTS

Body weights of the subjects were measured daily at the Hospital, and their initial body weights were maintained throughout the study

Glucose Responses to Meals

The serum glucose responses to the three grain meals are shown in Figure 1. At 30 min the glucose responses to rice meal(7.15 mmol/L) and potato meal (6.71 mmol/L)were significantly greater than the response to the buckwheat meal(5.85 mmol/L). The glucose responses to the rice meal at all times tested were greater than those to the buckwheat meal; consequently, the mean area under the glucose response curve following the rice meal was significantly greater than that following the buckwheat meal (18.87 vs 16.55 mmol/L) (Fig 2.). The

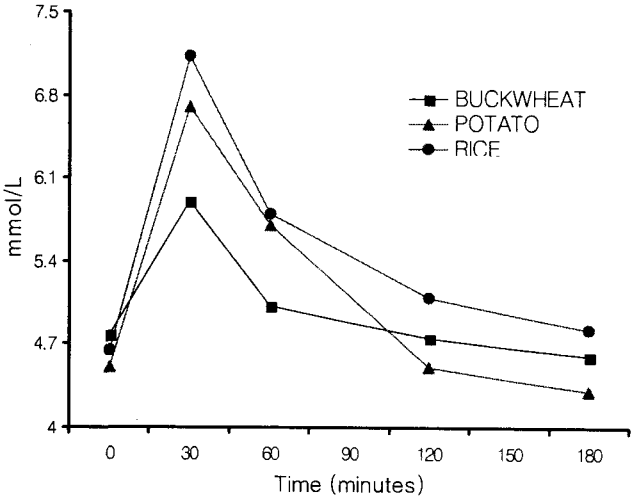

Fig. 1. Glucose Response to a Meal in Healthy Subjects.

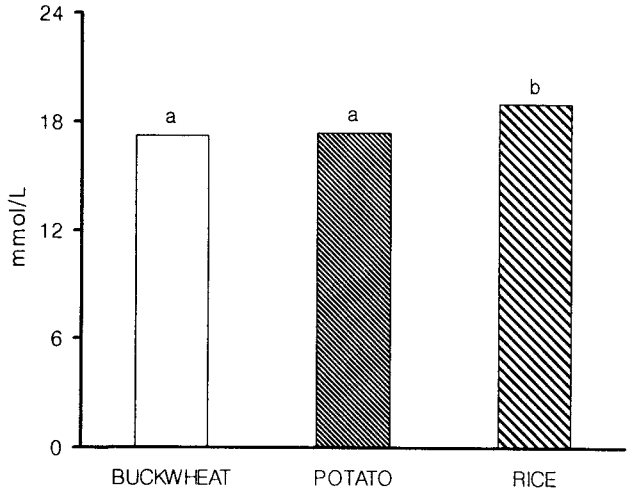

Fig. 2. Mean Areas Under Serum Glucose Response Curves.

glucose responses to the potato meal increased rapidly at 30 min and decreased sharply after then. The glucose responses to the potato meal at 30min and 60 min were greater than those to the buckwheat meal. However, they were reserved at 120 and 180 min. Therefore, the mean area under the glucose response curve was only slightly greater after the potato meal than after the buckwheat meal.

Insulin responses to meals

The serum insulin responses to the three grain meals are presented in Figure 3.The insulin responses to the potato and rice meals at 30 and 60 min were significantly greater than those to the buckwheat meal. The maximum peak of insulin responses to the rice and potato meal were obtained at 60 min, while the insulin peak after the buckwheat meal was obtained at 30 min. The mean area under the insulin response curve after the rice meal was significantly greater than the area for the buckwheat meal(7.01 $\mu g/L$ vs 4.21 $\mu g/L$). Like the glucose responses, the serum insulin responses to the potato meals at 30 and 60 min were greater than those to the buckwheat meal. They were reserved at 120 and 180 min. Thus, the mean area under the serum insulin response curve after the potato meal was slightly greater than that of the buckwheat meal(Fig.4). Blood lipids,

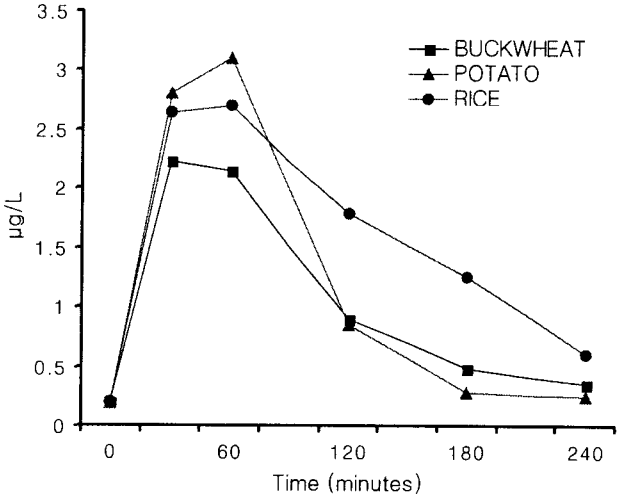

Fig. 3. Insulin Response to a Meal in Healthy Subjects.

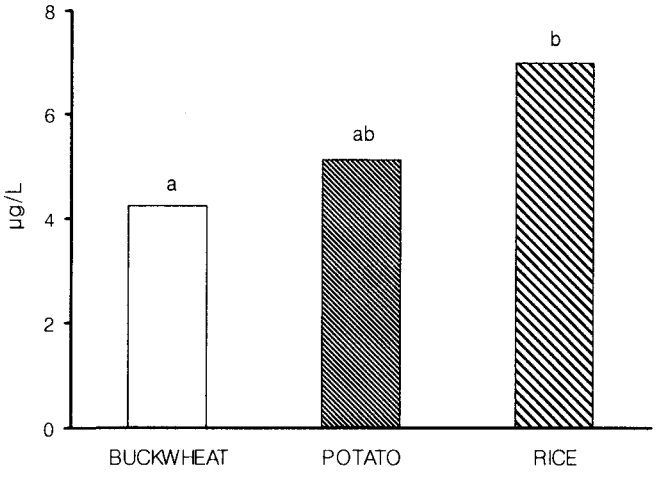

Fig. 4. Mean Areas Under Serum Insulin Response Curves.

uric acid and glycosylated hemoglobin are compared in Table 3. None of these parameters were significantly affected by the three grain meals. However, glycosylated hemoglobin levels showed pattern similar to the glycemic indices, i.e. it was greater after the rice meal, and smallest after the buckwheat meal.

Table 3. Comparisons of Blood Parameters.

Parameters	Buckwheat	Potato	Rice
Total Cholesterol (mg/dl)	146±8*	148±8	146±5
HDL-Cholesterol (mg/dl)	40±2	39±2	39±2
Triglycerides (mg/dl)	38±6	37±3	44±4
Uric acid (mg/dl)	4.4±0.4	5.0±0.3	4.7±0.3
Glycosylated Hb (g/dl)	4.8±0.4	5.0±0.5	5.4±0.3

* Mean±S.E.

DISCUSSION

The use of slowly digested carbohydrate sources has suggested to control of diabetes and hyperlipidemia(15-17). Previously, we observed that the digestion of cooked buckwheat was significantly slower as compared to either cooked potato or rice (unpublished data). The data from the current study show that long-term effects of equal amounts of carbohydrate from buckwheat appear to have more benefits than those from either rice or potato in healthy young subjects.

Since NIDDM is highly prevalent in Korean adult population who consume a short grain rice three times a day as a main dish and also consume potato frequently, it should be emphasized that this study was designed to assess the long-term effects of buckwheat, rice and potato cooked by Korean common recipe in healthy subjects consuming a typical Korean diet, i.e. high in carbohydrate, moderately high in protein., and low in fat. Thus, the menu provided respective grain as a main dish three times a day. We chose a short grain rice boiled in water in a rice cooker, peeled potato cooked in steamer, and buckwheat pancakes made only with water.

In korea, buckwheat noodles are more popular than buckwheat pancakes. However, it is impossible to make 100% buckwheat noodles because of its physical characteristics of little gelatinization and little stickness. To make buckwheat noodles, other kinds of starches, usually the potato starch should be added.

The physical form of grain is a critical factor determining the rate of starch hydrolysis(17,18) : decreased particle size and increased surface area of starch hydrolytic enzymes. We compared the effect of buckwheat flour on glycemic indices with those of whole grain rice and whole potato in the present study. Still, the buckwheat meal was digested slowly and showed lower and flatter glucose and insulin responses than either the rice meal or the potato meal.

At the present time, we cannot identify what factor are responsible for the results. Abundance of amylase is associated with lower initial response and slower declines in both glucose and insulin levels, and suggests the presence of a factor in high amylose rice which delays digestion and/or absorption of carbohydrate(19,20). Recently, Behall et al(21). evaluated the effort of the structure of the starch (amylose) compared with a mixture with 70% branched chain starch(amylopectin) on postprandial glucose and insulin responses. The high amylose meal lowered glucose and insulin response than the high amylopectin meal. According to the physical characteristics of little gelatination of buckwheat, it must have high amount of amylose. These physical characteristics are seen by the difficulties in making noodles. Pressed pure buckwheat noodles can hold no longer than 10 min. Therefore, any lose content of buckwheat may account for the result of this study.

The importance of viscosity in causing a delayed gastric emptying time and slowing carbohydrate absorption has been well established(22). Certain gelling fiber (guar gum, pectin), when mixed with glucose tolerance test or when enclosed in and item (pasta) of a test meal, cause a flattening of the postprandial glucose and insulin responses, attributable to the fiber viscosity(23,24). These types of fibers could also be considered. However, viscosity is also affected by a different amylose/amylopectin ratio of starches. In spite of definitely lower viscosity of amylose versus amylopectin, high amylose rice indices significantly lower plasma glucose(5,20).

Goddard et al(5,20). have proposed that amylose lipid complex control the digestion or absorption of the high-amylose rice. Buckwheat contains more fat than either rice or potato(Table 2). The amylose-lipid complex may also be partially responsible for the results.

Crapo et al.(25). compared the effect of equal amount of carbohydrate from baked potato and from boiled rice on postprandial glucose, and showed a greater glucose response after an ingestion of potato than after an ingestion of rice. A similar result was also obtained when rice or potato was given as part of a conventional meal(26). However, in the present study, the glucose and insulin responses to the rice meal were greater than those to the potato meal. The reason for the difference between those studies and the present study may be that we used a short grain rice that has high amylopectin, while they used a long grain rice that has high amylose.

It can be concluded from the results of the current study that the long-term use of buckwheat may protect the Korean population from developing the sign and symptoms of diabetes which may be outcome of the long-term use of a short grain rice and/or potato.

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