Short Communication

Natto and viscous vegetables in a Japanese style meal suppress postprandial glucose and insulin responses

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Naturally viscous vegetables and natto, made by fermenting soybeans, are very palatable and considered to be healthy foods in Japan. The objective was to assess whether the consumption of natto and viscous vegetables as part of a traditional Japanese breakfast based on high-glycemic index white rice affects glycemic, insulinemic, lipidemic and satiety responses in healthy subjects. Eleven healthy subjects consumed the reference, control and test meals in a randomized cross-over design. The test meal, comprising 200 g of boiled white rice with viscous meal (50 g natto, 60 g Japanese yams and 40 g okras), and the control meal, comprising 200 g of white rice with non-viscous boiled soybeans, potatoes and broccoli, contained comparable amounts of carbohydrate, fat, protein and fiber. In addition, whiter rice was used as a reference meal. Blood samples over 180 min were analyzed for glucose, insulin, non-esterified free fatty acid and triacylglyceride. Peak glucose and insulin concentrations after the test meal (6.0 mmol/L and 262 pmol/L) were significantly lower than after the control meal (6.8 mmol/L and 360 pmol/L). The incremental areas under the curve for glucose and insulin over 0-120 min after the test meal were also significantly reduced as compared with the control meal (28 and 27%). The consumption of naturally viscous vegetables with white rice reduced acute glycemia and insulinemia. This practical dietary combination would ensure compliance and favorably alter the risk for diabetes and cardiovascular diseases.

Key Words: postprandial glucose, insulin, viscous fiber, white rice, healthy subjects

INTRODUCTION

A diet producing a low glycemic response is associated with significantly less insulin resistance and significantly lower risk of type2 diabetes,[1] and risk of cardiovascular diseases.[2] One of the ingredients that have potential benefits for improving postprandial glycemia is the purified viscous forms of dietary fiber, such as guar and β-glucan.[3-5] At therapeutic doses, however, these ingredients may be associated with gastrointestinal side-effects,[3,4] and their palatability is extremely poor,[6] two features that can be significant barriers to long-term adherence to the use of these products.

In Japan, we have many naturally viscous foods, including vegetable, potatoes, mushrooms and seaweed. In particular, natto is a traditional and popular Japanese food, made by fermenting boiled soybeans with *Bacillus natto*,[7] that has viscous properties. The effects of these natural foods on postprandial glycemic and insulinemic responses are uncertain.

The purpose of the present study was to evaluate the effect of viscous foods, in a natural rather than purified form, taken as part of a realistic Japanese breakfast based on high-glycemic index white rice,[8,9] on postprandial glycemic, insulinemic and lipidemic responses and satiety in healthy subjects.

MATERIALS AND METHODS

Subjects

Eleven subjects (four men and seven women aged 23-33 yr) who had normal BMI and were healthy with no known medical conditions participated in the study. In all subjects, fasting plasma glucose concentrations were <5.1 mmol/L and serum insulin concentrations were within the normal range for healthy subjects.

Informed consent was obtained from each subject before enrollment, and the study was approved by the Ethics Committee of the Faculty of Medicine, Tokushima University, Tokushima, Japan.

Protocol

This randomized crossover study was conducted on three different days separated by weekly intervals. Five subjects out of eleven have had the test meal first, and then the control meal. Another six out of eleven have had the control meal first, then the test meal. The day before the test days, each subject consumed a standardization dinner and was asked to standardize their exercise and to refrain from consuming alcohol. After an overnight fast, venous blood samples were drawn before (0 min) and after (15, 30,

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Table 1. Composition of the test meals

	White rice (WR)	Test meal	Control meal
	WR 200 g	WR 200 g	WR 200 g
	-	Natto 50 g	Boiled soybeans 50 g
	-	Japanese yams 60 g	Potatoes 60 g
	-	Okras 40 g	Broccoli 40 g
	-	Soy sauce 6 g	Soy sauce 6 g
	Water 200 mL	Water 200 mL	Water 200 mL
Energy (kcal)	302	457	455
Carbohydrate (g)	69.4	87	87.5
Protein (g)	4.2	15.1	15.3
Fat (g)	0.8	6.1	5.6
Dietary fibers (g)	0.5	6.5	6.6
- insoluble (g)	0.5	4.7	5.5
- soluble (g)	-	1.8	1.1

45, 60, 90, 120 and 180 min) the test meal for the analysis of glucose, insulin, non-esterified free fatty acid (NEFA) and triacylglyceride (TG). Subjects were instructed to chew for the same number of times when eating the test and control meals within 18 min.

Visual analogue scale (VAS), 100 mm in length with words anchored at each end, expressing the most positive and the most negative rating, were used to assess satiety of the test meals at the same time points. Subjects did not discuss or compare their rating with each other and could not refer to their previous rating when marking the VAS.

Test meal

The test meal was designed to resemble a typical Japanese breakfast meal. The effects of white rice combined with viscous 50 g natto, 60 g Japanese yams and 40 g okras (test meal) and 200 g white rice combined with non-viscous 50 g boiled soybeans, 60 g potatoes and 40 g broccoli (control meal) were compared (Table 1). Boiled soybeans, potatoes, and broccoli as the control meal belong to the same food group of the viscous foods. These three control items are nutritionally identical to the three test items (natto and boiled soybeans, okras and broccoli, as well as Japanese yams and potatoes) except their viscosity. Meals were freshly prepared using a microwave oven and a fixed method with regard to the cooking time and preparation.

The reference food was 200 g of aseptic packed Satou Rice. This quantity of white rice is the mean of the standard amounts recommended for the Japanese population.

Laboratory analysis

Blood sample were centrifuged at 3500 × g for 10 min at

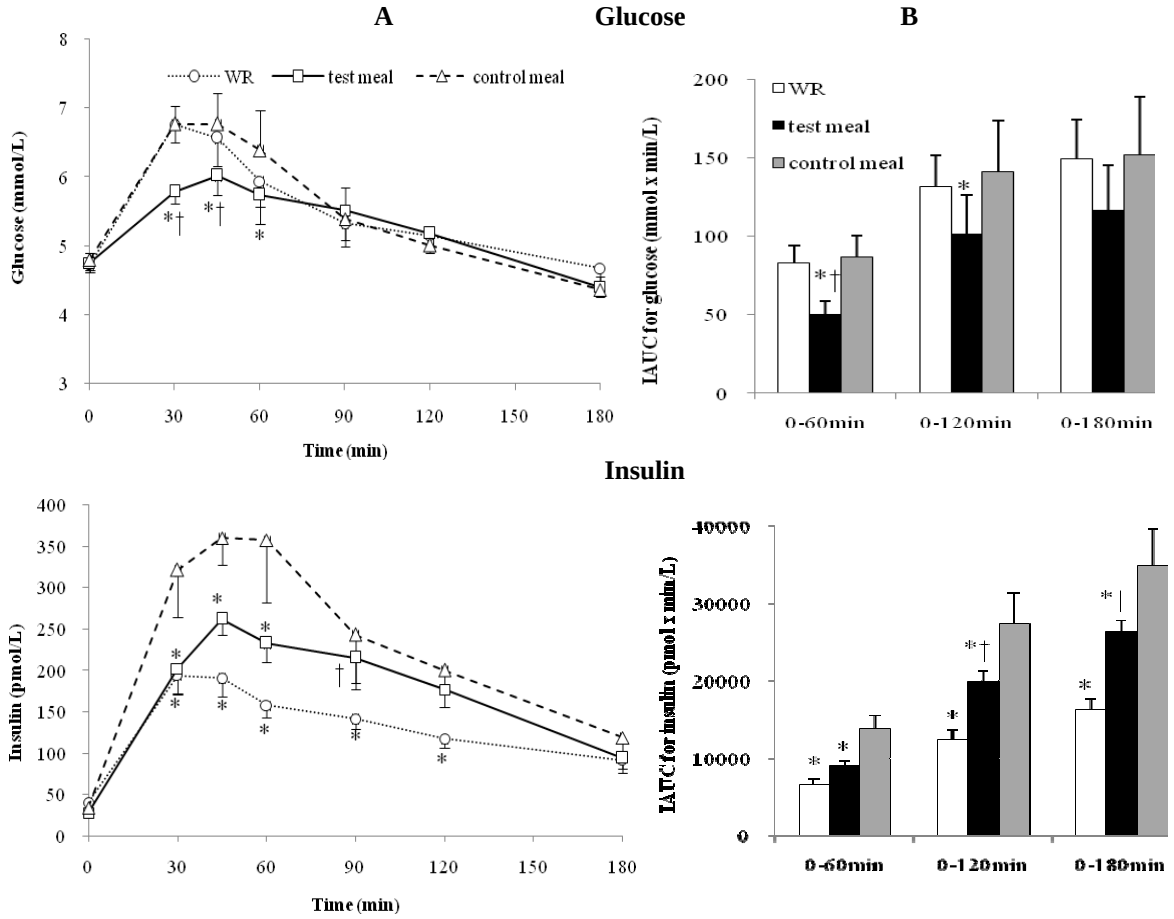

Figure 1. A: Mean (± SE) plasma glucose and serum insulin concentrations after mixed meals. B: Mean (± SE) areas under the curve (AUCs) for glucose and insulin calculated over 60-, 120- and 180-min periods after mixed meals. *Significantly different from the response to control meal, $p<0.05$. †Significantly different from the response to WR meal, $p<0.05$. WR: white rice.

4°C and then separated into plasma and serum. The plasma glucose concentration was measured by using a glucose oxidase-based autoanalyzer. The serum insulin concentration was measured by a standard radioimmunoassay. The serum TG and NEFA were measured both by enzymatic methods.

Calculations and statistical methods

The area under the curve (AUC) for glucose and insulin was calculated, and the areas below baseline were excluded from the calculation. All statistical calculations were performed with StatView software (SAS Institute Inc, Cary, NC, USA). Group differences were evaluated with a repeated-measures analysis of variance (ANOVA), followed by Fisher's PLSD post hoc test.

RESULTS

There was no significant difference in fasting values in subjects taking any of the 3 types of test.

The plasma glucose and serum insulin responses at 30, 45 and 60 min after the test meal was significantly lower than that after the control meal (Figure 1-A). Also, the glucose AUCs after the test meal were significantly lower (-42 and -28%) than those after the control meal for the

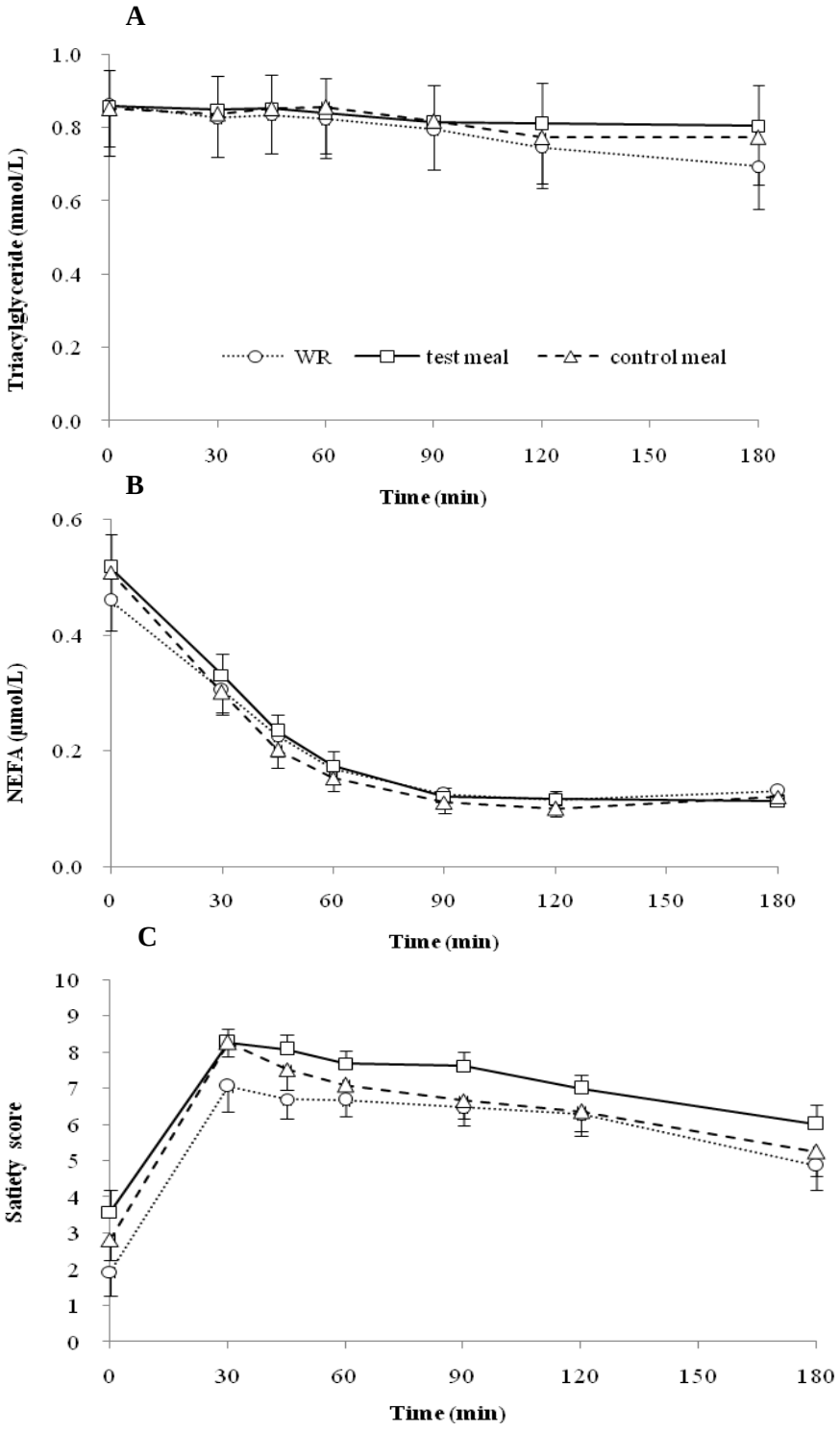

Figure 2. A: Mean (± SE) serum triacylglyceride concentrations after mixed meals. B: Mean (± SE) serum non-esterified free fatty acid (NEFA) concentrations after mixed meals. C: Mean (± SE) satiety responses assessed by a visual analog scale to mixed meals. No significant differences were observed. WR: white rice.

periods 0-60 and 0-120 min (Figure 1-B). The insulin AUCs after the test meal were significantly lower (-35, -27 and -25%) than those after the control meal for the time periods 0-60, 0-120 and 0-180 min.

The TG and NEFA responses did not show any differences among the 3 meals. (Figure 2-A, B). The result of the VAS for the indication of satiety is shown in Figure 2-C. Satiety after the test meal tended to be potent and prolonged as compared with the control meal.

DISCUSSION

The present study demonstrates that the consumption of natto and viscous vegetables combined with white rice improved not only the postprandial blood glucose but also insulin profiles in healthy young subjects. Unlike milk products that stimulate insulin secretion and lower the glucose response,[10] consumption of the viscous meal significantly lowered insulin demand. This may be beneficial because even short durations of hyperinsulinemia induce insulin resistance in healthy subjects.[11]

Although some clinical studies have been carried out on the acute and long-term effects of purified and isolated viscous fibers such as guar gum, pectin, β-glucan and psyllium added as supplements to high-carbohydrate diets on glycemic control,[3-5,12,13] a study on the effects of naturally viscous vegetables on the postprandial glucose and insulin response in healthy subjects has not previously reported. The viscous substance of natto is a polyglutamic acid associated with polysaccharide, and Japanese yam and okras contain polysaccharides such as mannan and pectin.

Soluble viscous fibers generally have a greater effect on carbohydrate metabolism in the small intestine by delaying gastric emptying, although a slowed rate of absorption may also play a role.[3, 4] Here, natural vegetables with viscosity might affect carbohydrate metabolism by a similar mechanism. For example, the prolonged satiety after the viscous meal, as assessed by visual analog scales, may reflect delayed gastric emptying.

The amount of soluble dietary fiber contained in the viscous meal was 1.8 g and there was negligible difference between the test meal and the control meal. This value is far below the 4-20 g of fiber per meal that has been used in most other studies where effects of purified viscous fibers have been seen on blood glucose and insulin concentrations.[3-5, 12, 13] Purified fibers generally have a lower molecular weight and particle size, which decreases linearly with the degree of hydration and physiological activity.[6] Thus, increases in postprandial glucose and insulin concentrations would be suppressed much more strongly by naturally viscous vegetables than by the purified form of viscous fibers.

We tested the effects of single 50 g natto, 60 g Japanese yams or 40 g okras with 200 g white rice on postprandial glucose responses in the preliminary experiments using self-administered blood glucose measuring device. Each food with white rice lowered peak response and delayed the time of peak response compared with white rice only (data have not shown). Since it was thought that the combination of viscous foods, which is very popular and common in Japanese meals, would have additive effects, we evaluated the combination effect of viscous foods. Furthermore, this combination was prepared according to a realistic menu and hence adapted to the participants' usual habits.

Interestingly, even though the test meal contained higher amount of carbohydrate (87 g) than the WR meal (60 g), it showed a lower glycemic response than did the WR meal. In contrast, the insulin responses after the WR meal were significantly lower than those after the test or control meal. Both carbohydrate and protein amounts can be stimulating factors of insulin secretion. These findings suggested that the evaluation as mixed meal, not each single food, is important to provide scientific evidence.

The viscous meal used in the present study with its normal 'diet' basis has no side-effects. Furthermore, naturally viscous vegetables can be purchased at any market in Japan. They are also less expensive and more palatable than α-glucosidase inhibitors or supplemental viscous fibers. These favorable features would ensure compliance in dietary treatment.

The amount of fat in a Japanese meal based on white rice as a staple food is low because white rice contains little fat and goes well with low-fat side dishes. The fact that the GI of foods can be reduced by adding fat has been demonstrated.[14] However, a high-fat diet induces hypertriacylglyceridemia, which induces insulin resistance[15] and has damaging effects on endothelial function, producing oxidative stress and inflammation.[16] Because the addition of a low-fat viscous side dish to white rice did not increase postprandial serum triacylglyceride, this combination may be effective for glycemic control, insulin resistance and cardiovascular diseases.

In summary, incorporating viscous foods into a high-carbohydrate/low-fat Japanese meal could prevent and treat diabetes and its complications. Although further studies for subjects with impaired glucose tolerance and with diabetes will be required, these findings in this study suggested health benefits of these viscous foods for Asian populations who consume white rice as a staple food.

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AUTHOR DISCLOSURES

Akiko Taniguchi, Hisami Yamanaka-Okumura, Yuka Nishida, Hironori Yamamoto, Yutaka Taketani, Eiji Takeda declare no conflicts of interest.

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日本膳食中納豆及黏性蔬菜可降低飯後血糖及胰島素反應

天然黏性蔬菜及經由黃豆發酵製成的納豆，這兩類食物於日本認為非常可口且健康之食物。實驗目標為評估健康受試者於日本傳統高昇糖指數的米飯早餐中，攝食納豆及黏性蔬菜，是否影響血糖、血中胰島素濃度、血脂及飽食反應。共有 11 位受試者參與，以隨機交叉設計讓受試者攝取參考餐、對照餐與實驗餐食。實驗餐食中，包含 200 g 白飯及黏性食物（納豆 50 g、日本山藥 60 g 及秋葵 40 g）；對照餐食包含 200 g 白飯及非黏性煮熟之黃豆、馬鈴薯及花椰菜，兩種餐食含相似量之碳水化合物、脂肪、蛋白質及纖維。此外以白飯作為參考餐。餐後 180 分鐘內間隔抽取血液樣本分析血糖、胰島素、非酯化游離脂肪酸及三酸甘油酯。攝食實驗餐食，血糖（6.0 mmol/L）及胰島素濃度（262 pmol/L）尖峰顯著低於對照餐食（6.8 mmol/L 及 360 pmol/L）。實驗餐後 0-120 分鐘內血糖及胰島素上升面積也顯著低於對照餐（28 及 27%）。攝食天然黏性蔬菜與白飯可降低急性高血糖及高胰島素濃度。這種實用的飲食結合，較易遵行並有利於減低糖尿病及心血管疾病風險。

關鍵字：餐後血糖、胰島素、黏性纖維、白飯、健康受試者