

Effects of added PGX[®], a novel functional fibre, on the glycaemic index of starchy foods

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Abstract

The development of lower-glycaemic index (GI) foods requires simple, palatable and healthy strategies. The objective of the present study was to determine the most effective dose of a novel viscous fibre supplement (PGX[®]) to be added to starchy foods to reduce their GI. Healthy subjects (*n* 10) consumed glucose sugar (50 g in water × 3) and six starchy foods with a range of GI values (52–72) along with 0 (inert fibre), 2.5 or 5 g granular PGX[®] dissolved in 250 ml water. GI testing according to ISO Standard 26642-2010 was used to determine the reduction in GI. PGX[®] significantly reduced the GI of all six foods (*P* < 0.001), with an average reduction of 19% for the 2.5 g dose and 30% for the 5 g dose, equivalent to a reducing the GI by 7 and 15 units, respectively. Consuming small quantities of the novel functional fibre PGX[®], mixed with water at the start of a meal, is an effective strategy to reduce the GI of common foods.

Key words: Viscous polysaccharides: Dietary fibre: Glycaemic index: PGX[®]: PolyGlycopleX[®]

Postprandial hyperglycaemia and compensatory hyperinsulinaemia are factors linked to the development of lifestyle-related chronic diseases, including obesity⁽¹⁾, type 2 diabetes⁽²⁾ and CHD⁽³⁾. Carbohydrates are the only food constituents that directly increase blood glucose concentration, yet the proportion of dietary energy consumed as carbohydrate is not linked either positively or negatively to disease risk^(4–6). In contrast, a large body of evidence suggests that dietary fibre and glycaemic index (GI)/glycaemic load (a measure of the glycaemic effect of the diet) have independent effects on the risk of chronic disease^(7–11). Developing palatable, high-fibre, low-GI foods is therefore a new challenge for the food industry.

Quality rather than quantity of fibre is a more important influence on postprandial glycaemia and the GI of foods. Indeed, among 121 foods of varying composition but equivalent energy content, increasing amounts of fibre predicted a marginally positive, rather than inverse, relationship to acute glycaemia and insulinaemia⁽¹²⁾. Soluble fibres that develop viscosity in solution are more likely to be associated with reduced glycaemia. Indeed, the higher the viscosity, the greater the improvement in glucose and lipid metabolism⁽¹³⁾. Unfortunately, in practice, both palatability and acceptability

of functional fibres decline with increasing viscosity⁽¹⁴⁾. In this context, PGX[®], a highly viscous polysaccharide complex, has been developed that demonstrates a delayed onset of peak viscosity, allowing for a more acceptable and easy-to-use functional fibre⁽¹⁵⁾. Jenkins *et al.*^(16,17) have demonstrated that PGX[®] reduces glycaemia in a dose-dependent manner when added to a glucose drink and carbohydrate-containing foods. Since the effect of viscous fibre may vary according to the conditions in the lumen of the gastrointestinal tract, we undertook a series of studies to investigate the effectiveness of two doses of PGX[®] dissolved in water on lowering the GI of a range of common starchy foods.

Materials and methods

The viscous polysaccharide used in the present study is sold as PolyGlycopleX[®] or PGX[®] (α -D-glucurono- α -D-manno- β -D-manno- β -D-glucosyl- α -L-gulurono- β -D-mannuronosyl- β -D-glucopyranosyl- β -D-mannan; PGX[®]; InovoBiologic, Inc., Calgary, AB, Canada). It is manufactured from highly purified polysaccharides derived from konjac, sodium alginate and xanthan gum by a proprietary process (EnviroSimplex[®]), forming a complex

Abbreviation: GI, glycaemic index.

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with a viscosity higher than any currently known individual polysaccharide. Although PGX[®] complex formation takes place at secondary and tertiary levels, the primary structures of the natural polysaccharides remain unchanged⁽¹⁵⁾. The final product is 87% dietary fibre, of which 82% is soluble. Previous studies have indicated that PGX[®] is well tolerated in human subjects⁽¹⁸⁾, has a no observed adverse effect level of 50 000 parts per million⁽¹⁹⁾ and has no mutagenic or genotoxic effects⁽²⁰⁾.

Subjects

A pool of twelve healthy subjects (seven females), with a mean age of 26.1 (SD 5.2) years and a BMI of 22.4 (SD 2.0) kg/m², was recruited through the Sydney University Glycemic Index Research Service volunteer roster. Entry criteria included BMI < 25 kg/m², fasting blood glucose < 5.5 mmol/l and no medication or supplements known to alter carbohydrate metabolism. The study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human subjects/patients were approved by the University of Sydney Human Ethics Committee (protocol no. 12 029). Written informed consent was obtained from all subjects.

Study design

The study was undertaken according to the ISO Standard for GI testing⁽²¹⁾. After a 10–12 h fast, ten subjects (from the pool of twelve) consumed in random order eighteen test meals (six different foods with three doses of PGX[®]) and three reference meals (50 g glucose in 250 ml water given on three separate occasions). Of the twelve subjects, six consumed all six food sets, four subjects consumed five sets and two consumed only three sets. Each dose of PGX[®] was dissolved in 2 × 250 ml water (0, 2.5 or 5 g) and consumed simultaneously with a 50 g carbohydrate portion of the following six starchy foods: white bread (Tip Top Wonderwhite; Goodman Fielder, Ryde, NSW, Australia), white rice (Uncle Ben's Jasmine Rice; Mars Canada, Bolton, Ontario, Canada), boiled potato (McCain Purely Potato Cubes; McCains, Wendouree, VIC, Australia), French fries (McCain Superfries;

McCains), cornflakes (Kellogg's, Melbourne, VIC, Australia) and oat porridge (Quaker Quick Oats; Peterborough, Ontario, Canada). For the control meal (0 dose PGX[®]), 5 g of a non-viscous dietary fibre (inulin, Orafit[®]; Beneo, Tienen, Belgium) were used in place of PGX[®]. Subjects consumed the meals with a washout period of at least 2 d between the tests. On arrival at the metabolic kitchen, subjects were weighed and two fasting blood samples were taken. The test meal and water containing PGX[®] were consumed simultaneously at an even pace within 10–12 min. Because PGX[®] develops viscosity slowly, the solutions were only slightly viscous by 10–12 min (< 1000 cps; S Wood, unpublished results). Further blood samples were taken at 15, 30, 45, 60, 90 and 120 min.

Blood glucose analysis

Fingerprick blood samples (0.8 ml) from warmed hands were collected into Eppendorf tubes containing 10 U heparin, centrifuged and the plasma stored on ice until same-day analysis in duplicate using a glucose hexokinase assay (Roche Diagnostic Systems, Sydney, NSW, Australia) for an automatic centrifugal spectrophotometric analyser (Roche/Hitachi 912[®]; Boehringer Mannheim GmbH, Mannheim, Germany) with internal controls.

Statistical analysis

For each test, the incremental area under the curve was calculated according to the trapezoidal method. Any area under the baseline (fasting value) was ignored. In each study, the results were analysed using a general linear model (ANOVA) for the incremental area under the curve, with treatment or food and time as fixed factors and subject as a random factor. PASW Statistics 18 (SPSS, Inc., Chicago, IL, USA) was used for all statistical analyses. Results are expressed as means with their standard errors.

Results

All test meals were palatable and well tolerated, and no adverse events were reported. The effect of PGX[®] at 0, 2.5 and 5 g doses on the GI of the six foods is illustrated in

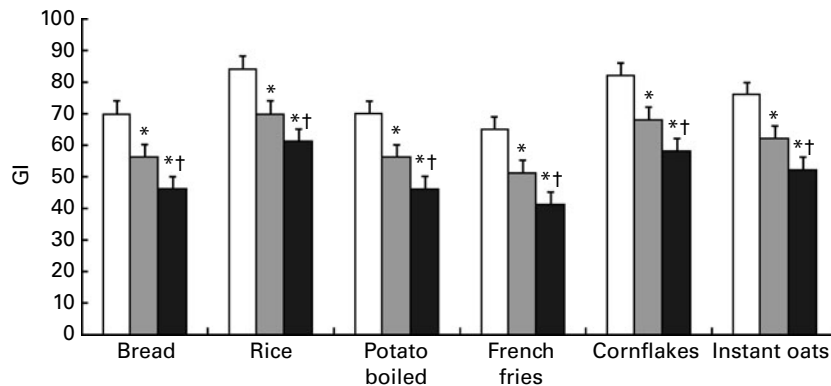


Fig. 1. Glycaemic index (GI) of starchy foods with 0 (□), 2.5 (▤) and 5 g (■) of PGX[®] fibre. Values are means (*n* 10), with standard errors represented by vertical bars (*n* 10). All dose levels were significantly different from each other, irrespective of food type ($P < 0.001$; ANOVA). * Mean value was significantly different from that of the no dose condition ($P < 0.001$). † Mean value was significantly different from that of the 2.5 g dose condition ($P < 0.001$). Without PGX[®], the mean GI values were as follows: bread 70 (SEM 3); rice 84 (SEM 4); potatoes (boiled) 70 (SEM 4); French fries 65 (SEM 4); cornflakes 82 (SEM 4); instant oats 76 (SEM 4).

Fig. 1. There were significant differences among the doses ($P < 0.001$), and each dose was significantly different from every other dose ($P < 0.001$). There was no significant food \times dose interaction, indicating that each dose affected each food in the same way. On average, a dose of 2.5 g reduced the GI by 14 units (i.e. by 16–22% depending on the food) and a dose of 5 g reduced the GI by 24 units (28–35% depending on the food). Using the logarithm of the GI, each dose of PGX[®] had a similar percentage reduction (21% for the 2.5 g dose and 33% for the 5 g dose), irrespective of the food (i.e. the food \times dose interaction was again not significant). This model was as good as the previous model using the GI alone and the percentage reduction.

Discussion

The present study shows that small quantities of PGX[®] dissolved in water and consumed with common starchy foods have clinically important dose-related effects on postprandial glycaemia. The smaller dose (2.5 g) reduced the blood glucose response to starchy foods by 21% and the higher dose (5 g) by 33%. PGX[®] reduced the GI of the foods by between 14 and 24 units (depending on the dose), irrespective of the food type. Notably, high-GI foods such as rice (GI = 84 in the present study) and intermediate-GI, higher-fat foods such as French fries (GI = 65 in the present study) were associated with a similar reduction in GI. All meals were well tolerated, with no reported gastrointestinal discomfort.

Alternative methods of incorporating PGX[®] are also effective in the context of single foods and mixed meals. Jenkins *et al.*⁽¹⁶⁾ demonstrated that sprinkling the product on the food just before consumption or direct inclusion during manufacture was successful in reducing glycaemia. They calculated that each gram of PGX[®] had the ability to reduce the GI by approximately 7 units. The term 'glycaemic reduction index potential' was used to describe this ability and allow comparisons among studies and different fibre preparations. In the present study, PGX[®] had a glycaemic reduction index potential value of 5–6 units, perhaps because PGX[®] was consumed in water with the meal rather than directly incorporated into the food.

The magnitude of the reduction in glycaemia achieved with PGX[®] is superior to many other commercially available functional fibre preparations⁽¹³⁾. Inulin, for example, is commonly added to commercial foods as a prebiotic fibre⁽²²⁾ but the 5 g dose used as the control (0 g PGX[®]) in the present study had no apparent effect on lowering GI. Cornflakes, for example, with 5 g inulin (0 dose of PGX[®]) generated a GI of 82, a value very close to the average of 81 in the published literature⁽²³⁾. Psyllium fibre can be consumed in solution or incorporated into foods such as breakfast cereal to reduce cholesterol absorption, but a 5 g dose produces only a modest 14% reduction in postprandial glycaemia⁽²⁴⁾. In contrast, 5 g PGX[®] produced a 33% reduction in the present study. β -Glucans (5 g) derived from oats consumed as a beverage reduced glycaemia by <20% when consumed with a bread meal⁽²⁵⁾. High-viscosity guar gum (approximately 5 g) can achieve a very high 50% reduction when intimately mixed with a meal but it is not effective when viscosity is low⁽²⁶⁾.

The effectiveness of various fibre preparations has been directly related to their ability to create viscosity⁽¹³⁾. Nonetheless, guar gum is so highly viscous in solution that its applications are limited due to stickiness and difficulties in incorporating the product into normal food processing operations. In contrast, the present study shows that PGX[®] reduces glycaemia very effectively when consumed in water before significant gelling has taken place. Guar is also notable for its capacity to produce excessive gastrointestinal discomfort⁽¹⁴⁾. In a double-blind, randomised controlled trial ($n = 54$), gastrointestinal symptoms after PGX[®] supplementation were rated as mild to moderate and generally well tolerated⁽¹⁸⁾.

In previous trials, we have demonstrated that the effectiveness of PGX[®] is dependent on dose, timing of consumption and physical form. Consumption within 15 min of the start of the meal, but not at 45 or 60 min, reduced glycaemia just as effectively as when taken with the meal. In contrast, PGX[®] consumed as capsules did not produce acute lowering of glycaemia, but had important 'second meal' effects, improving glucose tolerance at breakfast time when consumed with the previous evening meal.

Reducing postprandial glycaemia and dietary glycaemic load is a recent target in the management and prevention of obesity and type 2 diabetes^(27,28). A reduction in dietary GI and glycaemic load led to greater weight loss over 12 weeks⁽²⁹⁾ and improved maintenance of weight loss in a large European study⁽³⁰⁾. High-GI meals and diets are of greater concern in insulin-resistant individuals who must increase insulin secretion in order to re-establish glucose homeostasis, increasing the burden on the β -cell and therefore the risk of type 2 diabetes. In healthy adults, daily consumption of 5 g PGX[®] for 3 weeks was associated with improved insulin sensitivity and higher levels of peptide YY, a hormone that reduces hunger⁽³¹⁾. In adolescents, PGX[®] in solution (5 g) was shown to reduce energy intake from a pizza meal given 90 min later⁽³²⁾. In diabetic rats, PGX[®] was found to improve glycaemic control and protein glycation, most probably due to the insulin secretagogue effects of increased glucagon-like peptide 1⁽³³⁾. The ability of PGX[®] to reduce the glycaemic response may be a simple, effective ingredient in the design of lower-GI diets.

In conclusion, granular PGX[®] consumed in water with common starchy foods such as potatoes, bread and rice has biologically important dose-related effects on acute postprandial glycaemia. As little as 5 g reduced blood glucose responses over 120 min by 33% and reduced the GI of foods by 24 units.

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