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Original article

Effect of serving size and addition of sugar on the glycemic response elicited by oatmeal: A randomized, cross-over study

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SUMMARY

Background & aims: We aimed to determine the impact of serving size and addition of sucrose on the glycemic response elicited by oatmeal.
Methods: We studied 38 healthy subjects (mean ± SD age 40 ± 12 yr, BMI 26.4 ± 3.6 kg/m^2) on 8 separate days using a randomized, cross-over design. Capillary blood-glucose responses over 2hr after consuming 30, 40 and 60 g Classic Quaker Quick Oats (18, 24 and 36 g available-carbohydrate [avCHO], respectively) and 30 g Oats plus 9 g sucrose (27 g avCHO) were compared with those after avCHO-matched servings of Cream of Rice cereal (Control) (22, 29, 44 and 33 g cereal, respectively). Blood-glucose incremental area under the curve (iAUC), peak-rise, rate-of-decline, time-to-peak and time-to-baseline were calculated.
Results: As serving size increased, iAUC, peak-rise, rate-of-decline and time-to-baseline increased significantly for both cereals, but the rate of increase was significantly greater for Control than for Oats. Time-to-peak increased significantly with serving size only for Oats. Compared to avCHO-matched servings of Control, mean (95%CI) iAUC, peak-rise and rate-of-decline, respectively were 22 (16, 27)%, 22 (19, 26)% and 23 (18, 27)% lower after consuming Oats without sucrose and 26 (18, 34)%, 14 (9, 20)% and 16 (9, 24)% lower after consuming Oats plus sucrose.
Conclusions: Oatmeal elicited a significantly lower glycemic response than avCHO-matched servings of Cream of Rice, even when sucrose was added to the oatmeal. Measures of glycemic response tended to increase with increased serving size; although the pattern of change varied between cereal types. These results suggest that oatmeal may be a good choice for minimizing postprandial glycemia.
Clinical trial registry: ClinicalTrials.gov (NCT02506972).

1. Background

Oatmeal is rich in β-glucan, a highly viscous soluble dietary fiber found predominantly in the endospermic cell wall of oats and barley [1]. Oat β-glucan is a bio-active agent that plays a role in reducing postprandial blood glucose and insulin responses [2,3]. This is important because high postprandial glucose concentrations, even within the non-diabetic range, are associated with increased risk of cardiovascular disease [4], diabetes [5] and cancer [6]. Therefore, reducing postprandial glucose may benefit both people with and without diabetes.

β-glucan has been shown to reduce glycemic responses in normal subjects [7] and those with hypercholesterolemia [8], hypertension [9] and diabetes [10,11]. The mechanism of action of oat β-glucan is thought to be its ability to increase the viscosity of the contents of the upper gut [2,3], which, in turn, slows gastric emptying, decreases the accessibility of α-amylase to its substrate (starch) and increases the thickness of the so-called unstirred water layer in the small intestine, thus delaying the digestion and

Abbreviations: avCHO, available carbohydrate; iAUC, incremental area under the curve; C, concentration; EFSA, European Food Safety Authority; MW, molecular weight; OBG, oat beta-glucan.

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absorption of carbohydrates [12]. The viscosity of β-glucan is determined by molecular weight (MW) and concentration (C) [13]. Furthermore, concentration refers to the quantity dissolved per unit volume and, therefore, solubility is an important factor [14]. Significant inverse linear relationships between changes in peak blood glucose and log [C × MW] have been found not only for glucose solutions containing β-glucan [3] but also real food models [14,15]. Thus, in developing functional foods containing β-glucan, the maintenance of high MW and high solubility are essential.

An adequate amount of β-glucan per serving is also important for achieving reductions in postprandial glycemia. Recently, the European Food Safety Authority (EFSA) indicated that at least 4 g of oat or barley β-glucan per 30 g of available-carbohydrate (avCHO) is required to establish a claim of reduced post-prandial glycemia [16]. However, a review of 34 human studies by Tosh [17] shows that, for processed oat and barley foods, glycemic response is influenced more strongly by the dose of β-glucan ($r^2 = 0.48$, $p < 0.0001$) than by the ratio of β-glucan to avCHO ($r^2 = 0.25$, $p < 0.0001$). The review concludes that, for processed oat or barley foods, at least 4 g of high MW (>250,000 g/mol) β-glucan may lead to a physiologically significant reduction in postprandial glucose (27 ± 3 mmol × min/L) for meals containing 30–80 g of avCHO [17].

Oatmeal contains ~2.5 g β-glucan per 30 g avCHO and only ~1.5 g per 30 g serving, less than the amount required by the EFSA to claim a reduced glycemic response, and less than the amount required for a physiologically relevant reduction in postprandial glucose according to Tosh [17]. In addition, oatmeal often contains added sugar. These facts may cast doubt as to whether oatmeal has any benefit for reducing glycemic responses. Thus, the purpose of this study was to determine the impact of serving size and the addition of sugar on the glycemic response elicited by oatmeal compared to Cream of Rice, a sugar-free cereal low in β-glucan.

2. Methods

We studied the glycemic impact elicited by 8 different test meals in male and non-pregnant female subjects on separate occasions (at least 48 h apart) using an open label, randomized, cross-over design (Fig. 1). Subjects were non-smokers, aged 18–75 y, with body mass index (BMI) 20.0–34.9 kg/m^2, without diabetes, and in good health. Subjects who regularly took supplements and medications not considered to influence glycemic responses were allowed to participate. The protocol was approved by the Western Institutional Review Board® and each subject gave informed consent prior to participation. The trial was registered at ClinicalTrials.gov (NCT02506972).

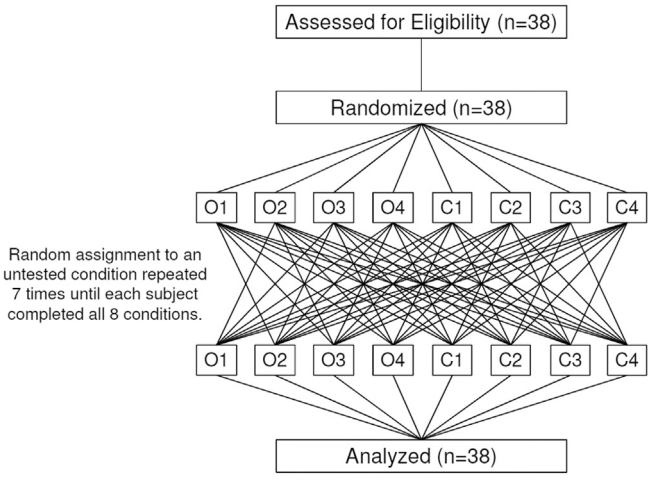

Fig. 1. Flow diagram.

2.1. Test meals

The composition of the test meals is shown in Table 1. Test meals consisted of various portions of Standard Classic Quaker Oatmeal (Oats; quick oats, composed of the oats variety HiFi which has a high β-glucan content) (Quaker, Chicago, IL) or Cream of Rice cereal (Control) (B&G Foods, Inc., Parsippany–Troy Hills, NJ) without milk. Cream of Rice was chosen as a control because it is served hot but is low in dietary fiber and sugar and devoid of β-glucan. The 30, 40 and 60 g portions of Oats, respectively, were prepared by adding 180, 240 or 360 g water, respectively, and cooking in a microwave oven on high for 2 min. Oats were then stirred and cooked for an additional 90 s (55 s for the largest dose), held for 3 min and then served to subjects. The 30 g portion of Oats was also tested with 9 g of added sucrose (27 g avCHO). The 22, 33, 29 and 44 g portions of Control were designed to contain the same amount of avCHO as the 4 Oat treatments (30 g, 30 g plus 9 g sucrose, 40 g and 60 g, respectively) and were prepared by adding water (120, 180, 160 and 240 g, respectively) cooking in a microwave oven on high for 3 min, stirring and holding for 3 min before serving. Water (250 ml) was served as a drink with each test meal.

2.2. Procedures

Subjects came to Glycemic Index Laboratories (20 Victoria St., 3rd Floor, Toronto) between 8 and 10 am after 10–12 h overnight fasts. Subsequent visits were scheduled at the same time as the first visit for each subject. Subjects were asked to maintain a normal diet and to avoid alcohol and unusually strenuous physical activity for 24hr prior to each visit. After reviewing the time and composition of the last meal of the previous day, assessing concurrent wellbeing, alcohol intake and physical activity over the previous 24hr, body weight was measured and 2 fasting finger stick blood samples (2–3 drops) were obtained at 5 min intervals. After the second fasting blood sample (0 min) a timer was started and participants began eating the assigned test meal which they were asked to complete within 10 min. Additional fingerprick blood samples were taken at 15, 30, 45, 60, 90 and 120 min after starting to eat. The order of the test meals using a table, provided by the sponsor's statistician, that contained 48 sequences chosen by conditional randomization from the 40,320 possible sequence order combinations.

Whole blood glucose was measured using a YSI model 2300 Glucose Analyzer (Yellow Springs, OH). Glucose was measured twice in the 0 min sample to calculate the SD of analytical variation as follows: $SD = \sqrt{(\sum d^2/2n)}$, where d is the difference between the 2 glucose measurements in the same blood sample and n is the number of pairs of blood samples in which duplicate measures were obtained. Data were entered into a spreadsheet by 2 different individuals and the values were compared to assure accurate transcription. To calculate area under the curve and peak-rise, fasting glucose was determined as the mean of the first glucose measurement at −5 and 0 min.

2.3. Power analysis

Our goal for this study was to have a high probability of detecting a physiologically significant reduction in incremental area under the curve (iAUC). For the power analysis, we assumed that a reduction in iAUC of 27 mmol × min/L (equivalent to a ~16% reduction from an average iAUC of 170 mmol × min/L) represented a physiologically significant effect [17], and that the average coefficient of variation (CV) of within-individual variation of AUC is