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Short communication

Food intake, postprandial glucose, insulin and subjective satiety responses to three different bread-based test meals☆

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ABSTRACT

The effect of bread consumption on overall food intake is poorly understood. The aim of this study was to measure postprandial food intake after a set breakfast containing three different breads. Ten males and 10 females aged 20.1–44.8 years, BMI 18.4–24.8 kg/m^2, consumed two slices of White Bread, Bürgen® Wholemeal and Seeds Bread or Lupin Bread (all 1300 kJ) with 10 g margarine and 30 g strawberry jam. Fullness and hunger responses and were measured before and during the test breakfasts. Glucose and insulin responses (incremental area under each two-hour curve (iAUC)) were calculated. Food intake was measured and energy and nutrient intake determined at a buffet meal two hours later. Subjects consumed significantly less energy after the Bürgen® Bread meal compared to the White Bread meal (2548 ± 218 vs. 3040 ± 328 kJ, Bürgen® Bread vs. White Bread, $P < 0.05$). There were higher fullness responses for the Lupin Bread ($P < 0.01$), and the Bürgen® Bread ($P < 0.05$) compared with the White Bread. Lupin Bread and Bürgen® Bread produced smaller postprandial glucose responses (79 ± 7, 74 ± 4, 120 ± 10 mmol/L min iAUC, Lupin, Bürgen® and White Bread respectively, $P < 0.01$). Differences in insulin responses were also observed (6145 ± 1048, 6471 ± 976, 9674 ± 1431 pmol/L min iAUC, Lupin, Bürgen® and White Bread respectively, $P < 0.01$). Equal-energy portions of three different commercially available breads differed in their short-term satiation capacity. Further studies are needed to demonstrate any potential benefit for weight management.

Introduction

Data from the Australian Longitudinal Study on Women's Health (2009) shows that 75.4% of women eat 2 slices of bread or less/day, compared with 64.1% of women in 2003 suggesting that women are eating less bread (http://www.alswh.org.au/). Reasons for this are unclear but it may be that bread is perceived to be fattening and therefore intake is limited (Nowak, 1998). Decreased consumption of wholemeal and wholegrain bread in both men and women has also been reported (Flood et al., 2010). Carbohydrate foods are frequently perceived unfavourably in both dieters and non-dieters (Winham, Collins, & Hutchins, 2009). The Australian Government Department of Agriculture Fisheries and Forestry in a report on The Australian Baking Industry (2010) found that 48% of people believe that eating too many carbohydrates is fattening (http://www.daff.gov.au/). Given the nutrient and fibre content of wholemeal and wholegrain bread and the proposed benefits of a high fibre diet it is concerning that bread intakes are reducing (Slavin, 2004).

Long-term consumption of a diet with a high glycaemic impact increases the risk of developing heart disease and diabetes (Krishnan et al., 2007; Levitan, Mittleman, & Wolk, 2010). Experimental studies show that low glycaemic index (GI) diets can improve short term blood glucose control and insulin sensitivity, and reduce lipid levels (Pereira, Swain, Goldfine, Rifai, & Ludwig, 2004; Reynolds, Stockmann, Atkinson, Denyer, & Brand-Miller, 2009; Slabber, Barnard, Kuyl, Dannhauser, & Schall, 1994) although 12 month studies have not confirmed a benefit in people with diabetes (Wolever et al., 2008). Low GI diets may reduce body fat to a greater extent than equal-calorie high GI diets in healthy people, which may reflect the greater insulin secretion and lower satiety associated with high GI foods (Bouché et al., 2002) although there are is also one negative study that did not show significant differences between low and high GI diets (Sichieri, Moura, Genelhu, Hu, & Willett, 2007).

The satiety index (SI) method was developed to rank equal-energy portions of different foods according to the extent to which they increased the feeling of fullness over a two-hour period (Holt, Brand-Miller, Petocz, & Farmakalidis, 1995). High-satiety foods were usually followed by reduced food intake indicating that the SI

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values were a valid measure of satiety and may have practical use (Holt et al., 1995). It has been shown that SI scores for bread can vary widely, ranging from 100% to 561%, with regular white bread having the lowest SI score. This suggests that the type of bread consumed may have an impact on satiety and food intake (Holt, Brand-Miller, & Stitt, 2001). The effects of bread intake and type of bread on overall food intake are poorly understood. The aim of this study was to measure food and energy intake two hours after the consumption of three test bread meals differing in their GI, protein, fibre and moisture content but similar in total energy. Secondary aims were to measure postprandial glucose, insulin and subjective satiety responses to the test meals.

Methods

Twenty healthy, non-smokers were recruited from the staff and students of the University of Sydney. Participants were excluded if they were dieting; restrained eaters as determined by The Three Factor Eating Questionnaire (Stunkard & Messick, 1985); had impaired glucose tolerance; were suffering from any illness or food allergy; or were taking prescription medication other than standard contraceptive medication. Study participants were 10 male, 10 female, aged 29.4 years (range: 20.1–44.8 years), BMI 21.8 kg/m^2 (range: 18.4–24.8 kg/m^2). The study was approved by the Human Research Ethics Committee of the University of Sydney. All participants provided written consent. The study was conducted using validated GI and satiety methodologies described previously (Holt et al., 1995; Wolever et al., 2003).

Three test breakfasts containing 1300 kJ consisting of two slices of bread with 30 g of strawberry jam (Golden Circle™ Strawberry 100% Spreadable fruit) and 10 g of polyunsaturated margarine (Flora® Original polyunsaturated margarine), were tested in a randomised cross-over design. Weights and nutrient contents of the test meals are shown in Table 1. The breads were; White Bread (George Weston Foods, Sydney, Australia), Bürgen® Wholemeal and Seeds Bread (Bürgen® Wholemeal and Seeds bread, George Weston Foods, Sydney, Australia) and Lupin Bread (Bodhi's Bakery, Fremantle, Australia).

Standard methodology was used to determine the satiety responses (Holt et al., 1995). Each study was completed on a separate morning with at least two days in between. The night before, the subjects ate a prepared standardised evening meal, and then fasted for at least 10 h. The subjects were required to avoid alcohol, excessive food intake (e.g. attending a banquet) and physical activity for the day before each study. The next morning, the subjects reported to the research centre in a fasted state and completed a baseline, fasting fullness/hunger rating on a category rating scale. Two fasting finger-prick blood samples (−5 and 0 min) were obtained (≥0.5 mL blood) using an automatic, non-reusable lancet device (Safe-T-Pro®, Boehringer Mannheim Gmbh, Mannheim, Germany). Subjects were then seated at a table and given one of the test bread meals which they consumed with 250 g of water within 12 min. Immediately after they finished the test breakfast subjects were asked to rate how much they liked the meal on a standard seven-point hedonic rating scale. The subjects remained at the research centre for the next two hours during which fullness ratings and blood samples were collected at 15, 30, 45, 60, 90 and 120 min after eating had commenced.

Subjects were asked to rate the degree to which they felt physically full at specific time-points on a seven-point equilateral category rating scale (RS) as described previously (Holt et al., 1995). The RS is anchored from left to right with the following categories: −3 ('extremely hungry'); −2 ('hungry'); −1 ('slightly hungry'); 0 ('no particular feeling'); +1 ('slightly full'); +2 ('full'); +3 ('extremely full'). The subjects were given a separate RS for each of their fullness ratings, and they could mark in between the categories if they desired. They were asked to focus on their true physical sensation of fullness or hunger, as opposed to appetite, when making each rating. After 120 min subjects were given a standardised food and beverage tray comprising white, wholemeal and grain bread, cheese, Vegemite™, peanut butter, honey, jam and margarine, Kellogg's Sustain™ and Special K™ and Lowan Natural Muesli, whole, reduced fat and skim milk, light fruit cake, Arnott's Shredded Wheatmeal and Morning Coffee™ biscuits, orange juice (Berri™), tea, coffee and sugar (three standard portions of each food and beverage). Subjects had 30 min to eat whatever they wanted. All food and beverages left on the tray were weighed and the amount of each item consumed recorded. The weight, energy, fat, saturated fat, protein, carbohydrate and fibre of the food consumed was calculated using manufacturer's data.

Each capillary finger-prick blood sample was centrifuged for 30 s immediately after collection. The plasma layer of the sample was collected into a labelled, uncoated microcentrifuge tube, and was immediately placed in a freezer and stored until analysis.

Plasma glucose concentration was analysed in duplicate using a glucose hexokinase enzymatic assay (Roche Diagnostic Systems, Sydney, Australia) and an automatic centrifugal spectrophotometric analyser (Roche/Hitachi 912®, Boehringer Mannheim Gmbh, Mannheim, Germany) with internal controls.

A two-hour plasma glucose response curve was constructed for each subject's test sessions using the average plasma glucose concentrations for each of their eight blood samples. The two fasting blood samples were averaged to provide one baseline glucose concentration. The incremental area under each two-hour plasma glucose curve (iAUC) was calculated in order to obtain a single number, which expresses the total increase in plasma glucose in that subject as a result of ingesting that food during the two-hour period.

Plasma insulin concentration was analysed using a solid-phase antibody-coated tube radioimmunoassay kit (Coat-A-Count® Insulin RIA kit, Diagnostic Products Corporation, Los Angeles, CA, USA) with internal controls. The two fasting blood samples were averaged to provide one baseline insulin concentration. A two-hour plasma insulin response curve was constructed for each of the

Table 1
Weights and nutrient contents of the test meals.

Test food	Amount (g)	Energy (kJ)	Protein (g)	Fat (g)	Available carbohydrate (g)	Fibre (g)
White Bread test meal	74 g bread 30 g jam 10 g margarine	1339	7.1	9.1	53.7	2.3
Bürgen® Bread test meal	83 g bread 30 g jam 10 g margarine	1329	11.3	13.2	36.9	8.6
Lupin Bread test meal	76 g bread 30 g jam 10 g margarine	1266	14.1	10.1	37.3	8.1