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Research report

Influence of whole grain barley, whole grain wheat, and refined rice-based foods on short-term satiety and energy intake

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ABSTRACT

This study compared the effect of whole grain high-fiber barley, whole grain wheat and refined rice-based foods on energy intake and satiety. Forty-seven healthy subjects consumed a breakfast of hot cereal and a snack mix containing either barley, wheat, or refined rice, followed by an ad libitum smorgasbord lunch using a crossover design. Energy intake was measured at the lunch using plate waste. Hunger, fullness, desire to eat, amount of food consumed, and thirst were assessed using a modified Visual Analog Scale (VAS) before and after the breakfast, snack and lunch. Energy intake at lunch did not differ among products. There were no differences in the area under the time curve in modified VAS scores among products for any parameter. However, subjects reported significantly less hunger before lunch compared to their hunger before breakfast when consuming the barley, but there was no significant reduction in hunger before lunch after consumption of wheat or rice. In conclusion, intake of a whole grain high-fiber barley, whole grain wheat, or refined rice breakfast and snack did not decrease energy intake acutely, but consumption of whole grain high-fiber barley foods significantly decreased hunger whereas whole wheat and refined rice foods did not.

Introduction

Obesity is a major health problem in the United States and in most other developed countries. Obesity contributes to chronic diseases such as heart disease and Type 2 diabetes (Ogden, Carroll, McDowell, & Flegal, 2007), and complications resulting from obesity are one of the leading causes of death in the U.S. (American Obesity Association, 2007). Results from the 2003–2004 NHANES data indicated that 66% of adults were overweight or obese with 32% considered obese (Center for Disease Control and Prevention, 2008). Although considerable effort has been focused on reducing obesity its prevalence is not declining (Ogden et al., 2007).

One approach that may aid in reducing obesity is consumption of foods that promote satiety. Satiety is commonly defined as the feeling of fullness from the consumption of a previous meal, which inhibits eating between meals (Gerstein, Woodward-Lopez, Evans, Kelsey, & Drewnowski, 2004). Dietary fiber, a component of whole grains, may act as a satiating ingredient. One group of dietary fibers, the soluble fibers, is usually viscous or gel-forming. Viscous dietary fibers, present in some whole grains such as oats and barley, create gastric distention and delay gastric emptying (Darwiche, Björgell, & Almér, 2003). Satiety-related hormones are then released, signaling fullness (Chaudhri, Salem, Murphy, & Bloom, 2008). Interestingly, both insoluble (Burley, Leeds, & Blundell, 1987; Delargy, O'Sullivan, Fletcher, & Blundell, 1997; Levine et al., 1989; Porikos & Hagamen, 1986; Turconi et al., 1995) and soluble (Adam & Westerterp-Plantenga, 2005; Chow et al., 2007; Tomlin, 1995; Williams, Noakes, Keogh, Foster, & Clifton, 2006) fibers have been shown to enhance satiety. However, some studies have found fiber to have no effect on satiety (Howarth et al., 2003; Mattes, 2007; Silberbauer, Frey-Rindova, & Langhans, 1996; Weickert et al., 2006).

Epidemiological studies suggest that consumption of whole grain foods are inversely associated with body mass index (BMI) (Jacobs, Meyer, Kushi, & Folsom, 1998; McKeown, Meigs, Liu, Wilson, & Jacques, 2002; Newby et al., 2003; Pereira et al., 1998; Rose, Hosig, Davy, Serrano, & Davis, 2007; Steffen et al., 2003) and weight gain in adulthood (Bazzano et al., 2005; Koh-Banerjee et al., 2004; Liu et al., 2003; Schulz, Nothlings, Hoffmann, Bergmann, & Boeing, 2005). Whole grains are known for their fiber content, and therefore lower energy density, and as a source of bioactive components, both of which may increase satiety and reduce energy intake (Slavin, 2003). Although a number of feeding studies of whole grain wheat and whole grain barley consumption have demonstrated enhanced satiety (Granfeldt, Liljeberg, Drews, Newman, & Bjorck, 1994; Holt & Miller, 1994; Kaplan &

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Greenwood, 2002; Liljeberg, Akerberg, & Bjorck, 1999; Melanson et al., 2006; Pai, Ghugre, & Udipi, 2005; Solah, Fenton, Kerr, Crosbie, & Siryani, 2007), the effect on energy intake has been inconsistent, with some reporting no effect on energy intake (Granfeldt et al., 1994; Holt & Miller, 1994; Liljeberg et al., 1999; Pai et al., 2005; Solah et al., 2007), while others report a reduced energy intake (Kaplan & Greenwood, 2002; Keogh, Lau, Noakes, Bowen, & Clifton, 2007; Melanson et al., 2006). Further, one whole grain study that examined wheat and oats found no effect on either energy intake or satiety (Berti, Riso, Brusamolino, & Porrini, 2005). Given the inconsistent findings regarding the effect of whole grain foods on energy intake and satiety, further research on this topic seems warranted.

Compared to other grains, barley contains a relatively high concentration of beta-glucan, a viscous and fermentable dietary fiber, and therefore may be highly satiating (Marciani et al., 2001; Massimino et al., 1998). The barley used in this study, Prowashonupana, is a waxy, hulless cultivar (Sustagrain®, ConAgra Foods Inc.) that contains a greater concentration of beta-glucan than other cultivars of barley. Approximately 50% of the dietary fiber in Prowashonupana is beta-glucan (Arndt, 2006). The purpose of this study was to examine the effect of foods incorporating this whole grain high-fiber barley, whole grain wheat, or refined rice on satiety and subsequent energy intake. These grains were chosen to help determine the relative satiating effects of products made from three different grains that differed in the type and amount of fiber when consumed at breakfast and as a mid-morning snack. We hypothesized that foods made with the whole grain high-fiber barley would induce greater satiety and a greater reduction in energy intake at an ad lib lunch compared to foods made using whole grain wheat or refined rice.

Methods

Subjects

Fifty subjects were recruited from the University of Minnesota and surrounding community. Inclusion criteria included men and women in good health between the ages of 18 and 65 who were not smokers, were not dieting to gain or lose weight, were not in athletic training, were not pregnant or breastfeeding, were not taking medications known to affect appetite, regularly ate three meals per day, and had no food allergies or extreme dislikes for the foods in the test meals. The Zung Self-Rating Scale (Zung, 1965), which assesses symptoms of depression, the short form of the Eating Attitudes Test (Garner & Garfinkel, 1979; Garner, Olmsted, Bohr, & Garfinkel, 1982), which evaluates disordered attitudes toward food, and the Eating Inventory (Stunkard & Messick, 1985), which measures tendency toward dietary restraint, disinhibition, and hunger, were used as exclusion criteria. Subjects were not included in the study if they scored >42 on the Zung Scale (indicative of depression), scored ≥ 20 on the Eating Attitudes Test (indicative of disordered eating), exhibited a tendency toward dietary restraint, disinhibition, or hunger, or had a measured BMI <18 or $>40\ kg/m^2$. Height and weight were self-reported at a pre-screening session in which subjects also completed the Eating Attitudes Test, Eating Inventory, and Zung Scale. The study coordinator recorded BMI from subjects' height and weight and test scores from the Eating Attitudes Test, Eating Inventory, and Zung Scale. Subjects signed informed consent forms and the protocol was reviewed and approved by the University of Minnesota Institutional Review Board.

Study design

The study was a single-blind, randomized crossover design with three grain-food products closely matched for energy content. Subjects were unaware of treatments, however test foods were of different color. During 3 different test days, with a 7-day washout period, six subjects reported to the study site for either a whole grain high-fiber barley, whole grain wheat, or refined rice breakfast and snack, followed by a smorgasbord lunch providing refined grain that was consumed ad libitum. Subjects consumed all meals in a personal cubicle to deter conversation about the test foods and visualization of consumption. The subjects could consume any and as many items from the lunch they were provided. In order to alleviate confounding between whole grain test foods and non-treatment whole grains, only refined grains were included in the lunch. Subjects were instructed to fast from 10:00 p.m. the previous night. Upon arrival on the test day, subjects completed a 100-mm modified version of the Visual Analog Scale (VAS) and Satiety Labeled Intensity Magnitude Scale (SLIM) regarding their hunger, fullness, desire to eat, amount of food they could consume, and thirst (Table 1) (Cardello, Schutz, Lesher, & Merrill, 2005). Directly after completing the modified VAS/SLIM questionnaire (8:00 a.m.), subjects consumed 56 g of a hot cereal, followed by 30 g of a snack mix of the same product at 10:00 a.m. At 11:30 a.m. subjects were given lunch: a tray of food that was more than one could normally consume in one sitting. The lunch nutrient content is shown in Table 2. The lunch consisted of a turkey sandwich on refined wheat bread with cheese, mustard, mayonnaise, yogurt, an apple, a banana, saltine crackers, chicken noodle soup, tomato soup, carrot sticks, cookies, potato chips, Sprite, Coke, Diet Coke, and water. Subjects had 20 min to consume the entire breakfast, 10 min to consume the entire snack mix, and 30 min to consume as much of the lunch as was desired. All subjects consumed foods within the allotted time. Consumption time was limited to ensure that all subjects rated modified VAS/SLIM parameters at the same time points. To determine energy intake differences at the lunch, food items were weighed and recorded before and after the lunch meal to determine the amount consumed. Energy

Table 1
Modified Visual Analog Scale (VAS)/Satiety Labeled Intensity Magnitude (SLIM) questions.

(1) How hungry do you feel at this moment? (0 = 'greatest imaginable hunger', 100 = 'greatest imaginable fullness')
(2) How strong is your desire to eat at this moment? (0 = 'least desire to eat', 100 = 'greatest desire to eat')
(3) How full does your stomach feel at this moment? (0 = 'greatest imaginable emptiness', 100 = 'greatest imaginable fullness')
(4) How much food do you think you could eat at this moment? (0 = 'smallest amount possible', 100 = 'largest amount possible')
(5) How thirsty do you feel at this moment? (0 = 'least imaginable thirst', 100 = 'greatest imaginable thirst')

Cardello et al. (2005).

Table 2
Ad libitum lunch nutrient content.

Macronutrient	Amount	Percent kcal
Serving (kg)	2.7	
Calories (kcal/kJ)	1737/7268	
Calories from fat (kcal/kJ)	470.9/1970	27.1
Total fat (g)	52.3	27.1
Cholesterol (mg)	101.9	
Sodium (mg)	5088	
Total carbohydrate (g)	277.3	63.9
Dietary fiber (g)	15.7	
Soluble fiber (g)	5.2	
Sugars (g)	162.5	
Protein (g)	49.7	11.4