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Whole grain rye breakfast — Sustained satiety during three weeks of regular consumption ☆

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ABSTRACT

Whole grain rye products have previously been shown to increase feelings of satiety for up to 8 h after intake under standardized conditions. This study was set out to investigate the sustainability of the satiating effect after regular consumption of breakfast meals with whole grain rye porridge or refined wheat bread. The study was randomized, cross-over and double-blind. Healthy subjects (n = 24) were randomly assigned to daily consumption of iso-caloric standardized breakfast meals with whole grain rye porridge or refined wheat bread for two 3-wk phases, separated by a wash out of 3–4 weeks. Each intervention phase had 3 scheduled visit days (days 1, 8 and 22) when appetite ratings (hunger, satiety and desire to eat) were registered for 24 h at standardized conditions. Orocecal transit time (salicylazosulfapyridine/sulfapyridine method) and breath hydrogen as an indicator of colonic fermentation were measured at day 8 of each 3-wk phase in a subgroup (n = 16). To investigate effects of breakfast on free-living food intake, 3-day weighed food diaries were self-registered during both intervention phases. Whole grain rye porridge breakfast resulted in higher ratings of satiety and lower hunger and desire to eat during 4 h post consumption compared to refined wheat bread breakfast ($p < 0.001$). This effect was sustained throughout the 3-wk study phases. Unlike previous studies, the effects did not persist into the afternoon (4–8 h). The orocecal transit times after consumption of both breakfasts were similar and in the range of 5–6 h. The rye porridge resulted in high levels of breath hydrogen 4–8 h after intake, showing extensive colonic fermentation. This was however not related to any changes in appetite during this time-period. There were no significant differences in self-reported macronutrient- and energy intake between diets. This study shows that the satiating effect of rye persists after repeated daily consumption for up to three weeks. Clinicaltrials.gov Identifier: NCT01117363.

1. Introduction

The intensity and duration of post meal feelings of satiety is not only dependent on the caloric content of foods eaten, but also on food composition. Whole grain and cereal dietary fiber have the potential to enhance the satiating capacity of meals [1–4], and a higher intake is associated with lower BMI in diverse populations [5–7]. Rye is a cereal especially high in dietary fiber and is traditionally consumed as whole grain [8]. Rye porridge made from whole grain rye flakes is a food that combines several factors known to affect satiety. In addition to the high fiber content, processing of rye kernels into flakes retains some original botanical structure. Food structure has been shown to alter metabolism of cereal grains [9,10] as well as satiety [11,12]. Intact structure of rye kernels resulted in suppressed hunger 4–8 h after consumption [13]. Further, porridge has a large volume and a low energy density due to its high water content, a food property with potential to increase within-meal satiety [14] and decrease food intake [15]. Whole grain rye porridge at breakfast resulted in increased post meal satiety when compared to iso-caloric refined wheat bread breakfast for up to 8 h under standardized conditions [13,16]. Thus the satiating capacity of whole grain rye porridge likely results from a combined effect of low energy density (high volume with low caloric value), high dietary fiber content and a naturally intact structure, and is thereby a promising candidate for the development of satiating foods and diets.

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Short-term appetite in response to a certain food may change following regular consumption as a result of learning and physiological adaptation. For clinical relevance it is important to verify that a first exposure response is sustained at regular consumption. Some recent studies found that initial short term effects on postprandial appetite changed after repeated exposure [17–19]. Initial differences between hunger ratings, following consumption of a fermented milk product with or without added fiber, disappeared after 6 weeks of regular intake, so that the initial difference between products was no longer evident [17]. Conversely, two products that upon first exposure exerted similar post meal satiety differed in effect after regular consumption during a weight maintenance phase of 18 weeks [18]. Sustained effect was shown in a shorter term study [19], where appetite ratings after consumption of fiber enriched yogurt were the same at first exposure as after 10 days of daily intake. In other studies reporting altered satiety over time, weight change is a primary outcome [20–22]. This complicates result interpretation since a change in body weight can result in changes in food metabolism including altered appetite.

Mechanisms underlying the satiating effect of foods involve neural and hormonal signaling throughout the gastrointestinal tract with the purpose of regulating further intake and optimizing digestion and absorption [23]. Early physiological events (2–3 h postprandial) after consumption of rye foods have been investigated, including appetite related hormones [3,12] and rate of gastric emptying [24]. Of interest is also how the later (4–8 h postprandial) satiating effect of rye foods is mediated. Feedback signaling in response to nutrients in duodenum, jejunum and ileum alters the release of digestive enzymes affecting stomach emptying rate and passage time through the small intestine [25], and also affects motivation to eat and energy intake. Dietary fiber is suggested to increase the feeling of fullness by constituting a physical barrier delaying digestion and absorption of nutrients, and some fibers have been shown to delay stomach emptying in humans [26,27] and small intestine transit time in dogs [28]. Further, colonic fermentation was related to increased plasma levels of satiety related hormones in [29,30]. High levels of colonic fermentation, indicated by increased breath hydrogen, have been associated with increased satiety [30,31]. Rye intake is known to increase the amount of digesta escaping small intestinal digestion and absorption and thereby provide material for colonic fermentation [32]. The effect is partly due to the high dietary fiber content of rye foods. These events may be involved in the satiating effect of rye foods.

The present study was designed to examine post meal satiety of whole grain rye porridge breakfast compared with iso-caloric refined wheat bread breakfast at regular consumption over periods of three weeks. Further, the effect of the breakfast meal on food intake in free-living conditions was assessed by self-weighed food diaries filled in during three consecutive days in each breakfast period. Additionally, transit time from ingestion of the breakfasts to arrival of unabsorbed material to the cecum was determined, and breath hydrogen was measured as an indicator of colonic fermentation, in order to investigate if these mechanisms were involved in the satiety response of the test foods.

2. Subjects and methods

2.1. Subjects

Recruitment of healthy men and women, aged between 18 and 60 years, was done by advertising in a local newspaper as well as on the homepage of the clinic where the study was performed (KPL Good Food Practice AB, Uppsala, Sweden). After filling out a web-based questionnaire, volunteers were booked in for a screening visit at the study center. Blood samples were taken in the fasted state for analysis of glucose, thyroid-stimulating hormone, hemoglobin and alanine aminotransferase. Included subjects were within a healthy range of these measures, indicating normal metabolism. Subjects' weight and height were measured with subjects wearing light indoor clothing and no shoes, and those with a BMI below 18 or above 27 kg/m^2 were excluded. Physical activity level (PAL) was assessed by a simplified questionnaire [33] and those with a high level (PAL > 1.8) were excluded. Cognitive and behavioral components of eating behavior were assessed using the Three Factor Eating Questionnaire [34] in a revised version [35], which had previously been translated and adapted to Swedish conditions [36]. Subjects were not included if scoring above a 65% cutoff for one or more of the three categories: cognitive restraint, uncontrolled eating or emotional eating. As part of the screening process a 3-day weighed food diary was completed over three consecutive baseline weekdays. Subjects were included only when reporting a mean energy intake between 1750 and 2750 kcal/day, as well as a daily routine of having breakfast, lunch and dinner. Further exclusion criteria were: aversion to porridge or any other food in the study diet; dieting or smoking; self-reported fluctuations in body weight of more than 10% during three months prior to screening; intake of any medicine likely to affect appetite or food intake; medical condition involving the gastrointestinal tract; pregnancy, lactating or a wish to become pregnant during the study period. Target sample size was 22 subjects [13,16]. Allowing for a for a drop-out rate of 10%, 27 subjects were randomized. For measures of orocecal transit time and breath hydrogen a smaller number of subjects were required and a subgroup (n = 16) was selected to participate in these measures [37]. Subjects were allocated to this subgroup based on their willingness and practical suitability for vein blood sampling.

Initial recruitment started in early March 2010 and the study was carried out during 11 wks continuing until end of May 2010. Written informed consent was obtained from each subject. The study was carried out in compliance with the Helsinki Declaration and was approved by the Ethics Committee at Uppsala University. The study was registered at clinicaltrials.gov.

2.2. Test products

Rye porridge was made from whole grain rye flakes, produced by steaming, cutting and rolling rye kernels (AXA Rågflingor, Lantmännen Cerealia, Järna, Sweden). One portion of porridge was made from rye flakes (55 g), and water (300 g) cooked in a microwave oven for 4 min at 750 W. On study visit days the same microwave oven was used for the preparation of all porridges.

The wheat bread used as reference was made by mixing refined wheat flour (2820 g, Bagerivetemjöl, Lantmännen Cerealia, Uppsala, Sweden), water (1500 g, 31 °C), fresh baker's yeast (180 g), rapeseed oil (150 g), syrup (150 g) and colorit soy (150 g, Ekströms, Eslöv, Sweden) for 7 min. Colorit is a soy based coloring agent that gives the bread a dark color without changing the flavor, texture or nutritional content of the bread. It was added to make the bread look like a whole grain rye bread. After mixing the dough (Varimixer, Bjørn, Denmark) for 5 min, it was left to rest at room temperature for at least 15 min before being cut into pieces (82.5 g) and shaped by hand to buns. After proving for 20 min (36 °C, 75% humidity) breads were baked at 200 °C for 8 min. The breads were allowed to cool at room temperature for approximately 2 h and were individually packed in plastic bags before being frozen.

The different characteristics of bread and porridge disallow full blinding. However, the subjects were blinded from knowing that the reference bread was made from refined wheat. Subjects and the people serving the breakfasts were unaware of the contents and possible effects of the products.

The whole grain rye flakes and refined wheat bread were analyzed for nutritional content (Table 1). Dietary fiber was analyzed as individual sugar residues and Klason lignin according to the Uppsala method [38] at the Swedish University of Agricultural Sciences (Uppsala, Sweden). Fructan content was quantified by a spectrophotometric method