Rye, Oats, and Weight Management

Rye and oats, used as whole grain in Northern Europe in breads and a variety of other foods, are good sources of dietary fiber and phytochemicals.

Intake of whole grain foods is associated with improved weight maintenance in population-level studies.

Rye bread and porridge, as well as foods containing oat β-glucan, have been shown to improve satiety.

Dietary fiber and whole grain foods are associated with reduced risk of chronic disease. One of the main risk factors of many diseases is obesity, the prevalence of which is increasing at a high speed throughout the world. While the clear reason for weight gain and the increase of adipose tissue mass is an imbalance between energy intake and expenditure, the current sedentary lifestyle and the daily tempting food offerings are both significant contributors. This has led to a large-scale research interest in the role of food properties on satiation, i.e., the feeling of fullness after a meal, and also in other regulatory mechanisms suggested to be involved in the control of food intake.

Cereal Foods, Obesity, and Chronic Disease

The intake of whole grain foods has been linked to a lower body mass index (BMI) in several studies, as reviewed recently by Harland and Garton (6). They analyzed 15 observational studies, concluding that an intake of about three servings of whole grains per day was associated with lower BMI and central adiposity. A lower BMI was also associated with an increased fiber intake of 9 g/day and a decreased fat intake of 11 g/day. An association between a higher intake of whole grains and cereal fiber with reduced BMI and waist circumference was also reported in a cross-sectional study by Newby, et al. (19). Good, et al. (5) performed another cross-sectional analysis among American women, concluding that, in this population, increased whole grain intake may contribute to a healthy body weight.

As compared to the large number of population-level studies with whole grain foods, the literature is limited concerning the human intervention studies of the effects of specific cereal food products on energy metabolism and the control of food intake. The role of dietary fiber in weight maintenance is generally recognized, with many suggested mechanisms (3,8,23). There is also increased interest in the role of various phytochemicals, as well as food structure, on postprandial metabolism and energy intake.

Control of Food Intake

The control of food intake is complex and results from multiple integrated neural and hormonal responses that originate in the brain, gastrointestinal (GI) tract, and adipose tissue. The ultimate regulation of food intake occurs in the brain. The hindbrain and hypothalamus are the principal sites in the brain that receive input from the GI tract and adipose tissue (4).

Multiple sites in the GI tract, including the stomach, proximal and distal small intestine, colon, and pancreas, are involved in the regulation of food intake. Ingested food evokes satiety in the GI tract primarily in two distinct ways: by mechanical stimulation and by the release of peptides. GI peptides of special interest in the regulation of food intake have been ghrelin, peptide YY (PYY), and glucagon-like peptide 1 (GLP-1). PYY and GLP-1 have been associated with increased satiety, whereas increased concentrations of ghrelin are associated with hunger. Food intake is also strongly

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doi:10.1094/CFW-55-2-0066
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66 / MARCH-APRIL 2010, VOL. 55, NO. 2
regulated by various environmental, social, cultural, psychological, and cognitive factors; the impact of these factors being in many cases the most dominant (26). Furthermore, various characteristics of food, such as nutrient composition, energy density, volume, texture, form, and palatability, are involved in the regulation of food intake. The composition and structure of food determine the gastric emptying and small intestine passage time, as well as what peptides are released in the GI tract during and after the meal and at what concentrations they are released. Among different dietary components, dietary fiber has received considerable interest; evidence is accumulating about its favorable effects on satiety, the amount of food eaten, and the regulation of body weight.

There are, however, differences among different types of dietary fibers in their ability to affect satiety and in the mechanisms by which they affect satiety (3,9,23). So far, the soluble, high-viscous fibers (e.g., oat β-glucan) and nonsoluble fibers (e.g., the bulk of wheat and rye) have both been found to be efficient in inducing satiety and/or promoting weight management. Soluble viscous fibers have been suggested to influence the regulation of food intake by retarding digestion by slowing down gastric emptying, the small intestine passage time, and the absorption rate of nutrients. This is believed to increase satiety by enhancing satiety-mediating signals to the central nervous system. A direct effect may be the decreased absorption of macronutrients because of the physical barrier formed by viscous dietary fibers. Indeed, viscosity has been shown to inversely affect hunger when subjects consumed beverages in which the viscosity was modified with a very small amount of microcrystalline cellulose (18), although opposite results on the effect of fiber viscosity on satiety have also been reported (13). The mechanism behind the satiating effects of nonsoluble dietary fibers is less well known, but is likely related to their bulking effects and their effects on the metabolism of colon microflora. Mechanisms by which dietary fiber could influence weight control are shown in Figure 1.

**Rye and Oat Foods in Nutrition**

Rye and oats are both minor cereals compared to wheat, but they have a long history of traditional uses, as well as several new product concepts (16,21). Both are typically used in whole grain breads, pasta, porridge, and breakfast cereals, as well as in different extruded products. Rye and oat fiber both contain arabinoxylan and β-glucan as major components; rye arabinoxylan being the major constituent (14). Oat fiber is known to be a good source of soluble β-glucan (16).

Rye and oats are also sources of many vitamins, minerals, and phytochemicals, which may have beneficial effects on maintaining the healthy homeostasis in the body. Rye and oat bran are commercially available and are used as fiber sources, particularly in baking applications. Oats have also been used as a raw material for the preparation of ingredients with high β-glucan content. Oat foods have also been shown to be suitable for celiac patients. While the effects of both rye and oat foods on glucose and lipid metabolism have often been studied, the literature on their effects on satiety and food intake-related hormonal regulation is more scarce. However, many studies have been reported very recently and will be discussed below.

**Rye Foods and Satiety**

A recent report on rye bread and porridge suggests that rye products may possess beneficial effects on appetite regulation (9,20). A porridge made of whole grain rye flake, when consumed at breakfast, gave prolonged satiety, as well as lowered hunger and a desire to eat as compared to refined wheat bread, for up to 8 hours after consumption (10). However, rye porridge did not reduce food intake at the following ad libitum meal. The rye porridge test meal contained more dietary fiber (8.7 g) than the wheat bread (1.8 g) portion used as a reference. The test meal was also more diluted in terms of energy due to the higher water and fiber contents.

Rye bread has repeatedly been shown to elicit lower postprandial insulin responses than white wheat bread, i.e., the insulin economy is better after rye consumption versus wheat bread consumption. This has been suggested to result from other factors than the fiber content of rye bread (12). Accordingly, the glucose and insulin responses of both endosperm and whole grain rye bread were lower than that of wheat bread (20). Interestingly, in the latter study, a low insulin response was also shown to be negatively correlated to subjective satiety at 3 hours after ingestion of the foods and to a more mild recovery of plasma ghrelin. The authors conclude that rye products possess beneficial appetite-regulating properties. Also, in the very recent study of Isaksson, et al. (11), it was shown that when rye bread is consumed as a breakfast meal, decreased feelings of hunger both before and after lunch resulted. Additionally, in their study, rye bran was an even more effective component than the inner parts of the grain.

In the study of Rosen, et al. (20), rye bran bread produced higher insulin responses than other rye products studied. It is thus clear that the fiber content itself does not explain the satiety-modulating properties in rye products. Rye arabinoxylan, often further solubilized in processing, may also play an indirect role by changing the texture of the food. Currently, the search for the “rye factor”—the different postprandial properties of rye versus wheat bread—is going on in Nordic research groups.

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**Fig. 1.** Physiological responses of dietary fiber affecting body weight.

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**DIETARY FIBER**

- Small intestinal effects
- Colonic effects
- Hormonal effects
- Whole body effects

**FOOD**

- Energy density
- Palatability
- Structure

**Behavioral effects**

- Intestinal viscosity
- Postprandial glucose
- Insulin secretion
- Insulin sensitivity
- Adipose tissue metabolism

**BODY WEIGHT**

- Satiation, satiety, energy intake
Oats, Satiety, and Weight Management

Oat β-glucan is a mixed-linkage, water-soluble, high-molecular weight polysaccharide. It forms a viscous solution even at low concentrations; the viscosity depends on the molecular weight, solubility, and concentration of β-glucan. The viscosity-forming capacity of oat β-glucan has been suggested to be crucial for its effect on satiety-related attributes (24). In our study (17), the viscosity of soluble fibers, guar gum, and oat β-glucan had a role in their ability to increase satiety in healthy humans. Beverages containing wheat bran, guar gum, or oat β-glucan (10 g/portion) were used as test foods. The results showed that the most viscous beverage, containing guar gum, had the clearest effect on satiety compared to the beverage without fiber. The beverage containing oat β-glucan increased fullness and showed a trend of increasing satiety more compared to the reference beverage. Thus, it seems that adding oat β-glucan to beverages could boost their satiating capacity compared to beverages without fiber.

In another study, we measured the post-prandial satiety-related perceptions using beverages as a model food; the beverages contained either 5 or 10 g of oat β-glucan/portion. Compared to a reference beverage without fiber, the beverages containing 5 or 10 g of oat β-glucan had a larger area under curve (AUC) for perceived satiety and a smaller AUC for hunger, but no statistically significant dose-response relationship was detected. In addition, the lowering of a beverage’s viscosity, containing 10 g of β-glucan, by enzymatic treatment reduced the satiating effect, which stayed higher than that of a beverage without β-glucan. Thus, it seems that oat β-glucan could potentially increase postprandial satiety-related perceptions even though its viscosity has been lowered. In fact, another study of our group (13) showed that a beverage with enzymatically lowered viscosity increased satiety even more than a beverage with its natural viscosity, containing the same amount (10 g of β-glucan). This is in contrast to results from some earlier studies where increased viscosity was shown to enhance satiety. However, it should be noted that the low-viscosity beverage still contained hydrolyzed β-glucan as a fiber source, which together with more rapid absorption of nutrients (due to lowered viscosity) might have augmented satiety.

Only a few other studies have reported the use of oat β-glucan. Howarth, et al. (9) compared a mixture of pectin and β-glucan with methylcellulose for 3 weeks at a daily dose of 27 g (2:1 ratio of pectin to β-glucan) in a gelatine-like pudding, showing that methylcellulose was slightly more satiating than the pectin/β-glucan mixture. Muesli was used as a carrier food for 4 g of oat β-glucan in a study by Hlebowicz, et al. (7), and they did not detect any effect of the addition of β-glucan on satiety as compared to a portion of cornflakes with the same caloric content.

Both of the latter studies using oat β-glucan had solid or semisolid foods as carrier food matrices. Because liquid foods have a weaker decreasing effect on hunger and a weaker increasing effect on satiety compared to solid foods (15), it is possible that the larger satiating effect of solid food easily masks the satiating potential of fiber.

Extruded cereals with varying doses of oat β-glucan (2.16–5.68 g/serving) were used in a study where overweight subjects consumed five different breakfasts (2). Together with increased satiety (at a dose of 2.2 g) and decreased energy intake at subsequent ad libitum meal (at a dose >5 g), β-glucan increased plasma cholecystokinin (CCK) levels in a dose-responsive manner, indicating beneficial effects of β-glucan on postprandial appetite control and GI peptide release.

The effects of β-glucan have also been investigated in some longer term studies. In a study by Beck, et al. (1), the effects of daily β-glucan consumption (three energy-restricted diets: a control diet and two diets with 5–6 g or 8–9 g of β-glucan, respectively) were studied in a group of overweight women for 3 months. The addition of β-glucan did not improve weight loss or the effect of energy restriction on weight loss despite the increased CCK responses, but it did decrease the levels of GLP-1 and PYY at the end of the study. The discrepancy in GI peptide responses may partly explain the lack of improved satiety during the study.

In another longer term study (22), healthy subjects consumed an energy-restricted diet for 6 weeks, either consuming a diet low in soluble fiber or a diet with 5–6 g or 8–9 g of β-glucan, respectively. Both of the latter studies using oat β-glucan have also been reported better satiety.

Concluding Remarks

A body of evidence shows that the consumption of whole grains has favorable effects on weight control and overall health status. The recent results from rye and oat studies support these findings, showing enhanced postprandial satiety effects, especially in rye bread and porridge, as well as beverages and extruded products containing oat β-glucan. However, these studies are still scarce, although they exceed in number the trials performed to examine the effects of satiety on other cereal foods.

However, the long-term studies with oat-based foods assessing weight loss directly have been less encouraging, although even more scarce in number. The inconsistent results of the short- and long-term studies do, however, suggest that in the longer term, some other factors, such as environmental, social, and psychological factors, are still more powerful determinants of food intake and body weight. In the future, more long-term studies are, however, warranted to indicate the distinct role of specific food factors on appetite and further on the control of body weight. Oats and rye, among other cereal grains, are important raw materials for a healthy diet and are suitable also for weight management. They also represent staple foods that offer potential alternatives for nutritionally inferior components in the diet.

References


