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Whole grain cereal food in prevention of obesity

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Review

Abstract

Whole grain food is important part of human nutrition providing a wide range of vitamins, minerals, antioxidants, phytosterols and other phytochemicals. Regular consumption of whole grain cereals is associated with decreased risk of cardiovascular disease, diabetes, colon cancer and obesity. Whole grain food and, especially, dietary fiber are drawing attention due to many potential benefits. They decrease weight, body-mass index, the waist circumference and waist-to-hip ratio by lowering the amount of accumulated body fat. There is lack of precise explanations of underlying mechanisms but it has been proven that the risk of obesity may be reduced by replacing of refined cereal sources with more whole grain, high-fiber and low glycaemic index food. Whole grain cereals and dietary fiber in particular enhance satiety, promote satiation, prolong gastric emptying time and slow nutrient absorption. Synergic effect of many beneficial components such as fiber, resistant starch and antioxidants may be responsible for slowing the rate of glucose absorption, delaying insulin release and blunting glycaemic response, what may influence weight management.

Keywords: whole grain foods, dietary fiber, overweight, obesity, prevention, satiation, satiety

Introduction

Nowadays, obesity is an alarming problem not only in developed but also in developing countries with its attendant risk of cardiovascular disease, diabetes mellitus 2, arthritis and some cancer types (Hainer et al. 2008, Caballero 2007). The increase of obesity, defined as an excess amount of body fat, is a global trend, not only confined to affluent societies but also seen in emerging countries, such as China and others. Obesity is currently the most common metabolic disease in the world, although the prevalence varies widely among different continents and countries. Obviously, there are some other influences beyond the genetic background, namely cultural and lifestyle, which could explain these differences. But what is really most disturbing is the rising and progressive tendency of obesity expansion (Formiguera and Cantón 2004).

The rate of obesity is high also in Slovak Republic and other European countries. The study conducted by Dukát et al. (2007) showed that only one of three adult inhabitants of Slovakia have a normal body weight and almost every second inhabitant has intra-abdominal obesity according to waist circumference (> 102 cm in men; > 88 cm in women). Obesity was registered in every third woman (34.7 %) and in every fourth man (27.0 %). The situation in Czech Republic is similar, referring 29.5 % of men and 28.1 % of women being obese (Cerveny et al. 2007).

The main cause of obesity is energy intake from food and drink in excess of expenditure from physical activity and other metabolic processes. The negative energy balance induced by the treatment of obesity should lead to a reduction of fat stores and an appropriate preservation of lean body mass. Obesity treatment should be individually tailored and the age, sex, degree of obesity and individual health risks should be taken into account. There are many approaches how to fight this worldwide problem and behavioral modification of lifestyle should be included in all weight management strategies. Self-control over daily energy balance composing of dietary intake and physical activity plays a crucial role in long-term success of weight loss and even more in weight maintenance (Hainer et al. 2008).

There are number of reasons why prevention is likely to be the only effective way of tackling the problem of overweight and obesity. The prevention of weight gain and the maintenance of healthy weight would be easier, less expensive and potentially more effective than to treat obesity after it has fully developed. Key elements of a weight gain prevention plan are diet (reducing energy intake) and physical activity behavior (increasing energy expenditure) (Gill 2005).

Many different types of diet and their effectiveness for treating overweight have been compared by various authors (Sacks et al. 2009, Shai et al. 2008, McMillan-Price et al. 2006, Dansinger et al. 2005). Weight control strategies based on exclusion of carbohydrates such as Atkins diet are attracting attention (Boslaugh 2008) but it ignores the fact that digestible carbohydrates provide the same amount of energy per gram as protein and less than 45% of the energy derived from fat or 60% of the energy obtained from alcohol (Topping and Cobiac 2005). Moreover, several unfavorable effects of low-carbohydrate diet administration have been demonstrated such as increased loss of lean body mass, increased levels of low density cholesterol and uric acid (Hainer et al. 2008). On the contrary, high carbohydrate diets, especially with low glycaemic index (rich in whole-grains), also lead to significant body fat loss and additionally, reduce cardiovascular disease risk (McMillan-Price et al. 2006, Liu 2008).

The aim of this review was to summarize the current research concerning whole grain foods and whole grain fractions such as dietary fiber in the prevention and treatment of overweight and obesity. Possible mechanisms on the regulation of weight of the most accentuated component of cereals, such as dietary fiber are discussed.

Whole grain cereal food and nutrition

What are whole grains (WG)? American Association of Cereal Chemists applies following definition: WG shall consist of the intact, ground, cracked or flaked caryopsis, whose principal anatomical components (the starchy endosperm, germ and bran) are present in the same relative proportions as they exist in the intact caryopsis. More consumer friendly definition is that WG foods are those from flour that contains all the components in approximately the same proportion as the original grain (Jones 2005, Smith-Edge et al. 2005). Components such as germ and bran are rich source of fiber, minerals, vitamins, lignans and other phytochemicals, for instance antioxidants, which may offer important health benefits such as lowered risk for cardiovascular disease, diabetes mellitus 2, cancer and all-cause mortality (de Munter et al. 2007, Kajaba 2003). Moreover, WG are not only a rich source of minerals, but some dietary fiber constituents such as inulin are also believed to improve minerals absorption, for example to enhance uptake of calcium by altering the pH value in the colon (Chawla and Patil 2010). On the other side, it is important to mention that outer parts of the grains may be a source of elements such as heavy metals or pesticide residua which may be harmful to human body (Havrlentová et al. 2011).

Chemical and morphological composition of whole grains

Most whole-grain kernels are composed of about 80% endosperm (rich in starch and protein, but poor in most micronutrients), 15% bran (a major source of fiber, micronutrients, antioxidants and phytochemicals) and 5% germ (also rich in micronutrients and phytochemicals) (Anderson 2004, de Munter et al. 2007). The structure of a whole grain is shown in Figure 1. In the refining process, components of the grain that are part of the bran and germ are lost, including fiber, minerals, vitamins, lignans and other phytochemicals (de Munter et al. 2007). The known compositional differences between whole wheat and refined wheat, as well as between whole-meal flour and white "refined" flour are shown in Table 1. All nutrients with potential preventive actions against lifestyle diseases are reduced. Some antioxidants such as Se, Mn, Zn and vitamin E are reduced by as much as 79-92 %.

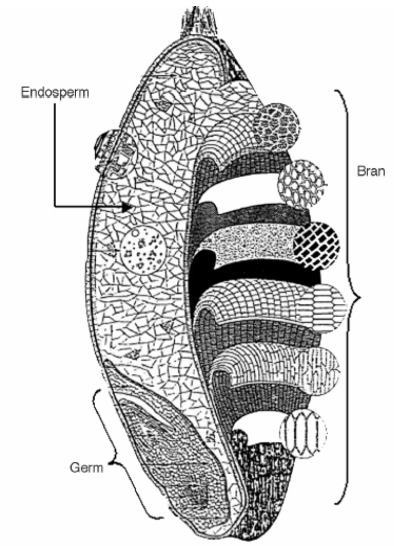

Figure 1. Structure of a whole grain (Slavin 2004).

Table 1. Compositional differences between whole/refined wheat and flour.

Components (SLAVIN et al. 1999)	Unit	WHOLE WHEAT	REFINED WHEAT
BRAN	%	14	< 0,1
GERM	%	2,5	< 0,1
Nutrients			
Total dietary fiber	%	13	3
Insoluble dietary fiber	%	11,5	1,9
Soluble dietary fiber	%	1,1	1,0
Protein	%	14	14
Fat	%	2,7	1,4
Starch and sugar	%	70	83
Total minerals	%	1,8	0,6
Selected minerals			
Zinc	μg/g	29	8
Iron	μg/g	35	13
Selenium	μg/g	0,06	0,02
Selected vitamins			
Vitamin B6	mg/g	7,5	1,4
Folic acid	mg/g	0,57	0,11
Phenolic compounds			
Ferulic acid	mg^{-2}/g	5	0,4
β-tocotrienol	μg/g	32,8	5,7
Phytate phosphorus	mg/g	2,9	0,1

Table 1. Continued.

Components pro 1kg (SMITH et al. 2003)	Unit	WHOLE-MEAL FLOUR	WHITE UNFORTIFIED FLOUR
Total dietary fiber	g	90	31
Protein	g	127	94
Fat	g	22	13
Carbohydrate	g	639	777
Starch	g	618	762
Sugars	g	21	15
Na	mg	30	30
K	mg	3400	1500
Ca	mg	380	150
Mg	mg	1200	200
P	mg	3200	1100
Fe	mg	39	15
Cu	mg	4,5	1,5
Zn	mg	29	6
Cl	mg	380	810
Mn	mg	31	6
Se	μg	530	40
Vitamin E	mg	14	3
Thiamin	mg	4,7	1
Riboflavin	mg	0,9	0,3
Niacin	mg	57	7
Vitamin B_6	mg	5	1,5
Folate	μg	570	220
Panthotenate	mg	8	3
Biotin	μg	70	10

The health benefits of whole grain cereals

Whole grain cereals are important dietary components providing a huge range of nutrients and phytochemicals, which can have synergistic effect in promoting health. Regular consumption of WG foods has been associated with a reduced risk of several chronic diseases, and mortality (Jacobs et al. 2001, Slavin et al. 2001), although their exact role in disease prevention is not yet fully elucidated (Smith et al. 2003, Pickard 2005, Newby et al. 2007). Many epidemiologic studies have shown that the consumption of WG is associated with a significantly lower risk of cardiovascular disease (Lang and Jebb 2005, Jensen et al. 2006, Anderson 2003, Seal 2006, Okarter and Liu 2010) what confirmed also Katcher et al. (2008) in the 12 week long, randomized study. It is suggested that bran fraction rich in dietary fiber, β-glucans, vitamins, minerals, antioxidants, lignans and other phytochemicals can contribute to this protective effect. The consumption of whole grains including bran is further linked to protection against insulin resistance and thus diabetes (Lang and Jebb 2005, Hallfrisch et al.

2000, Jensen et al. 2006, Pereira et al. 2002, Murtaugh et al. 2003) and obesity (Duchoňová and Šturdík 2010). Moreover, folate, vitamin B12, antioxidants and micronutrients such as zinc or selenium present in whole grains have been associated with lowered depression (Logan 2006). The summary of health benefits of WG consumption is outlined in Figure 2.

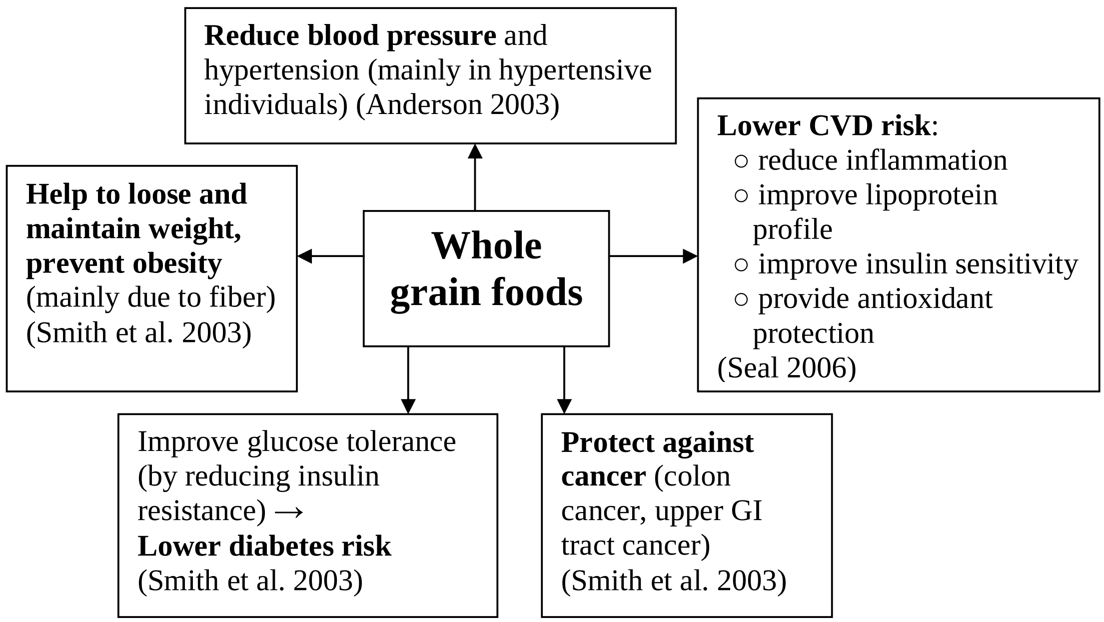

Figure 2. The dominant health benefits of whole grain foods and their components such as dietary fiber. CVD - cardiovascular disease, GI - gastrointestinal tract.

Whole grain cereal foods consumption as a weight loss strategy

Overweight and obesity are the result of long-term imbalance between energy intake and energy expenditure. One of the strategies to improve nutrition and energy intake is to increase consumption of whole grains (de Vijver et al. 2009). Whole grains and, especially, dietary fiber received specific attention, and many studies have been conducted to evaluate their health benefits. Whole grain cereals intake is inversely related to body-mass index- BMI (Steffen et al. 2003, Bazzano 2005, Koh-Banarjee et al. 2004, Gaesser 2007, van de Vijver et al., 2009) and waist-to-hip ratio or waist circumference. Their consumption appears to prevent weight gain (Liu et al. 2003) or to help losing weight (Jones 2005, Anderson 2003, Melanson 2006).

Williams et al. (2004) reviewed 53 studies regarding the role of cereal grains and legumes in the prevention or management of overweight and obesity. There is good evidence from both epidemiological and intervention studies that a diet high in whole grains is associated with lower BMI, waist circumference and risk of being overweight. There is lack of precise mechanisms explanation and it is unclear to what extent the fiber content, glycaemic index, nutrient density or other features (such as impact of gut flora) of the grain foods causes the health effect. The author concluded that the risk of obesity may be reduced by replacing refined cereal sources with more wholegrain, high-fiber, and low glycaemic index grain foods, but further randomized trials are necessary to determine the absolute effect and to guide new product development. Kendall et al. (2010) also accentuated the importance of GI diet in weight management in his review.

Gaesser (2007) reviewed the quantity but also quality of carbohydrate intake in relation to BMI. Whole grain intake was consistently associated with lower BMI what may be due in part to dietary fiber. Cereal fiber, in particular, appears to play beneficial role in weight control. Several factors may explain the influence of whole grains and their components on body-weight regulation. Whole grains may enhance satiety (delayed return of hunger after a meal) or promote satiation (satisfaction of appetite that develop during the course of eating and eventually results in the cessation of eating). Viscous soluble fiber- rich grains tend to prolong gastric emptying time, and slow nutrient absorption in the small intestine (Slavin 2004, Slavin 2005, Brownlee 2011). Whole grains also provide slowly digested and resistant starch which can delay insulin release, blunt glycaemic response and thereby influence weight management (Jones 2005).

Cereal dietary fiber and control of body weight

A huge number of definitions of dietary fiber exist. Some of them are based on analytical method used to isolate and quantify dietary fiber (AOAC method 985.29) whereas other definitions are physiologically based (e.g., dividing fiber into soluble and insoluble).

Fiber encompasses both dietary fiber and added fiber. Dietary fiber is defined by the US National Academy of Sciences as nondigestible carbohydrates and lignin that are intrinsic and intact in plants, while added fiber includes isolated, nondigestible carbohydrates that have beneficial physiological effects in humans. Sources of dietary fiber include whole grains, fruit and vegetables, while sources of added fiber include fiber supplements in pill or functional food form (Dutia 2008). Some authors (Liu 2007, Slavin 2008) integrate into the definition of dietary fiber also other plant carbohydrates that are not recovered by ethanol precipitation, for example inulin and some resistant starch. Examples of food components which can be understand as a dietary fiber are shown in Table 2.

Table 2. Characteristics of dietary fiber (adapted from Slavin 2005).

Characteristics	**Dietary fiber**
Nondigestible animal carbohydrate	No
Carbohydrates nonrecovered by alcohol precipitation*	Yes
Nondigestible mono- and disaccharides and polyols	No
Lignin	Yes
Resistant starch	Some
Intact, naturally occurring food source only	Yes

*includes inulin, oligosaccharides, fructans, polydextrose, methylcellulose, resistant maltodextrins etc.

Whole grain fiber includes mainly cellulose, hemicellulose, lignin, inulin, β-glucans, resistant starch and other constituents of the grain. Major components of dietary fiber from various food sources are outlined in Table 3.

Table 3. Major components of dietary fiber (Johnson 2005).

Food source	**Polysaccharides and related substances**
Cereals	Cellulose, arabinoxylans, glucoarabinoxylans, β-D-glucans, lignin and phenolic esters
Fruit and vegetables	Cellulose, xyloglucans, arabinogalactans, pectic substances, Glycoproteins
Legume seeds	Cellulose, xyloglucans, galactomannans, pectic substances
Manufactured products	Gums (guar gum, gum arabic), alginates, carrageenan, modified cellulose gums (methyl cellulose, carboxymethyl cellulose)

The most studied dietary fiber components according to Liu (2007) are inulin and resistant starch. Inulin, when ingested, acts as prebiotic to stimulate the growth of healthy intestinal microflora (Kajaba 2004, Chawla and Patil 2010). Resistant starch resists upper intestinal digestion and pass into the lower intestine to be fermented by microflora in the colon. Short chain fatty acids are formed playing a pivotal role in colon health (Scott et al. 2008). The physiological functions of resistant starch include improving glycaemic response and colon health, providing bulk and thus decreasing caloric intake, modulating lipid oxidation and metabolism. Other very interesting fiber component groups are cereal β-glucans

(Havrlentová et al. 2011, Wood 2007, Kajaba 2004). The schematic effect of dietary fiber and its hormonal, intrinsic and colonic function are shown in Figure 3.

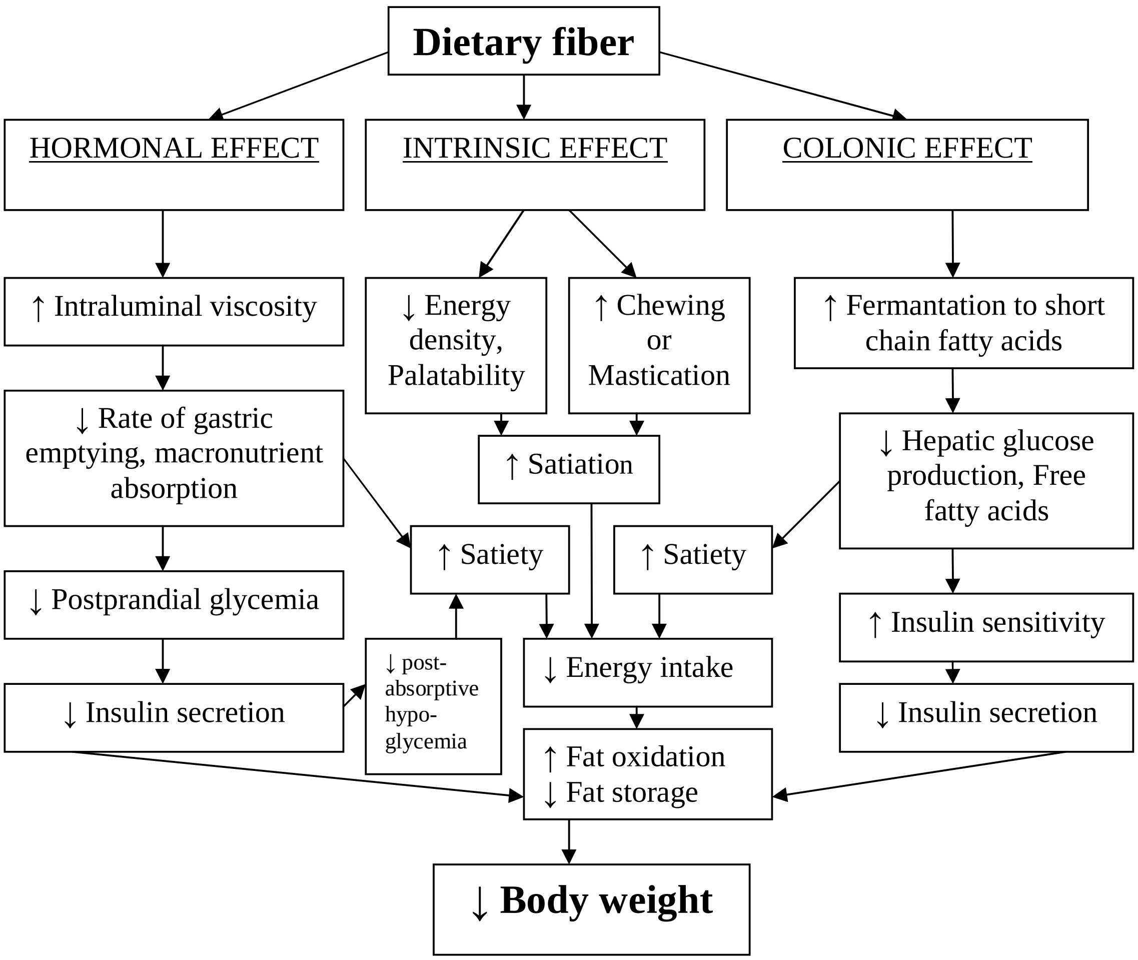

Figure 3. Schematic effect of dietary fiber with its hormonal, intrinsic and colonic effect (adapted from Slavin 2005).

Promotion of satiation and satiety

A meal rich in fiber is processed more slowly and absorption of nutrients occurs over longer period of time. One of the factors is the need to disrupt and disperse food particles adequately what appears to delay the digestive process (Johnson 2005). Moreover, a diet providing adequate fiber is usually less energy dense and larger in volume that may limit spontaneous intake of energy (Slavin 2008). Besides, larger mass of food is eaten longer and the presence of food in stomach may provide the feeling of satiety sooner. Also the number of chews necessary to eat the same energy equivalent of food may have an important satiating effect (Leeds 2005). An example was showed in 1992 by measuring the feeling of fullness of ten healthy subjects after eating seven different types of bread (equal-energy portions). Satiety scores of the breads were positively associated with portion size (energy density), total carbohydrate and fiber content of the breads (Slavin 2005). Similar effect have been demonstrated by measuring satiety and plasma and insulin responses after ingestion of four carbohydrate test meals (based on whole grains, cracked grains, coarse and fine whole-meal flour). The whole grain test meal gave the highest satiety response and the lowest insulin response as predicted (Smith et al. 2003). Isaksson et al. (2008) found out that whole grain rye porridge served at breakfast had prolonged satiation effect and lowered feeling of hunger in comparison with refined wheat bread. Kim et al. (2006) examined the short-term satiating effect of whole grains (wheat and barley) with various amounts of β-glucan. The consumption of 1-2 g β-glucan per meal served as hot cereal didn't show an effect on satiety and energy intake. The sourdough wheat-rye bread with added 10% of extruded wheat bran and 12.5% of β-glucan hydrogel did not show any statistical significant effect on satiety in 10 healthy non-smoker males compared with the standard wheat-rye bread (Mikušová, unpublished). 41g of insoluble fiber in the form of wheat bran reduced food intake independent of its weight and volume, but this effect is not maintained after 120 minutes (Freeland et al. 2009).

Lairon (2007) summarized results of 27 reviews and concluded that most of them showed an increased fiber intake connected with reduced energy intake of about 10%, but other studies reported mixed conclusions whether a fiber-rich meal can promote satiety and satiation or not. Source of fiber seems to play an important role in having impact as a bulking agent in the stomach.

Alteration of glycaemic or insulin response

Biomarkers are needed to determine the relationship between whole-grain intake and the metabolism of glucose and insulin. One marker used to compare the glycaemic response to food is glycaemic index- GI (Slavin 2003). The GI is defined as the area under the curve of glucose response after consumption of 50g available carbohydrates from a test food divided by the area under the curve after consumption of 50g carbohydrate from a control food (either white bread or glucose). Many factors together including type of carbohydrate, fiber, protein, fat, food form and structure and also method of preparation assess the GI of the particular food (Ludwig 2000, Wolever et al. 2003, Brennan et al. 2005, ISO 26642: 2010).

Higher GI foods induce higher insulin levels and c-peptide (peptide made when pro-insulin is split into insulin and c-peptide) excretion in comparison with lower GI food. The functional hyper-insulinaemia associated with high GI diet may promote weight gain by directing nutrients away from oxidation in muscle and guiding them preferentially to storage as fat. Furthermore, hormonal response to a high GI diet appear to lower circulating levels of metabolic fuels, stimulate hunger and favor storage of fat which may lead to excessive weight gain (Ludwig 2000).

Impact of fiber in food may be seen as slowed glucose appearance in blood and subsequently decreased secretion of insulin. The beneficial effects are most evident in individuals with diabetes mellitus because in healthy individuals is the whole process too rapid (Slavin 2005). One of the possible mechanisms suggests Slavin et al. (2008). Soluble fiber increases viscosity of the contents in the stomach and digestive tract what may be responsible for trapping nutrients and thus emptying of the stomach is delayed and glycaemic responses slowed. Lower blood glucose levels and decreased insulin secretion have been observed in both normal and diabetic subjects consuming low GI diet based on pumpernickel bread with intact whole grains, parboiled wheat, pasta and legumes in comparison with subjects on high GI diet containing wheat bread and potatoes (Slavin 2003). Another research was conducted to evaluate the factors affecting human glucose and insulin responses. It was showed that postprandial blood glucose and insulin levels are more affected by food form and botanical structure than by the amount of fiber or type of cereal used in the test food (Juntenen et al. 2002). Kendall et al. (2010) summarize that there is still much debate related to the possible mechanism of action for the role of high fiber and low GI in the diets. He concludes that the majority of current evidences support the idea that consumption of low GI foods high in fiber improve weight management and can be an effective tool in weight loss.

The effect on nutrient absorption and gastric emptying

Dietary fiber, especially the soluble one, results in highly viscous intestinal contents with gel-like properties which may delay gastric emptying causing extended feeling of fullness and/or may delay intestinal absorption of nutrients including glucose. As the consequence, postprandial glycaemic and insulin responses are blunt what is linked to reductions of hunger return and subsequent energy intake (Banarjee and Rimm 2003). While such absorption-lowering effect can have a benefit in reducing energy uptake, it must be noted that such factors are likely to reduce the bioavailability of minerals, vitamins and phytochemicals (Brownlee 2011). Juntenen et al. (2002) used paracetamol to evaluate the rate of gastric emptying after ingestion of four cereal test meals. Similar plasma responses were found after consumption of high fiber meals (whole kernel rye bread, whole meal rye bread with added β-glucan concentrate), positive control (dark wheat durum pasta showing low glucose response) and white wheat reference bread. These authors summarized also results from other studies, showing inconsistent conclusions. Six mentioned studies confirmed that soluble viscous fiber may slow or delay gastric emptying whereas the cellulose type of insoluble fiber has no influence (one study). Mourot et al. (1988) studied the relationship between the rates of gastric emptying and glucose and insulin responses to starchy food (mashed potatoes, French bread, rice and spaghetti). They concluded that the form of food (mainly particle size or processing) is more essential in the regulation of gastric emptying than the fiber content. Brennan (2005) suggests that dietary fiber inclusion can decrease the digestibility of cereal products. The amount of GI decrease depends on the type of fiber, recipe and level of addition. Furthermore, the structure of food products is very important when creating lowered glycaemic response of food.

The most studied area of dietary fiber effects on gastric motility is linked to gastric emptying. As a whole, the evidence suggests that the viscosity of dietary fibers may not be the most important factor. Nutrient content of the luminal fluid is more important predictor of gastric emptying rates than luminal viscosity. The variance between outcomes of studies could be a result of differences in used methodologies.

The intake of dietary fiber-rich food is generally associated with a reduced whole gut transit time (within the large intestine), what is believed to be a consequence of increased luminal bulk resulting in increased peristaltic. Rapid transit may be beneficial in reducing the high luminal toxicity occurring in large bowel as a result of damaging factors of endogenous, bacterial and dietary origin (Brownlee 2011).

Effects on gut hormones secretion

Satiety may be measured also objectively by determining the concentration of satiety – related hormones such as glucagon-like peptide-1 (GLP-1), peptide tyrosin – tyrosin (PYY), leptin, ghrelin, cholecystokinin and others (Schroeder et al. 2009). Dietary fiber may alter responses and actions of the circulating satiety – related gut hormones (gastric inhibitory peptide = GIP, GLP-1 and cholecystokinin) independently of glycaemic response. They may act as satiety factors or alter glucose homeostasis. Cholecystokinin, peptide hormone and neurotransmitter secreted in the small intestine after ingestion of food, stimulates pancreatic secretion, regulate gastric emptying and central inducement of satiety. Several authors reported a direct correlation between postprandial cholecystokinin and subjective satiety scores after fiber-different meals (Koh-Banerjee and Rimm 2003, Slavin 2005). Juntenen et al. (2002) monitored the responses of GIP and GLP-1 after ingestion of four different grain product including rye bread and pasta and control white wheat bread (discussed above). Whole grain rye breads and pasta showed lower GIP al GLP-1 responses in comparison with white wheat bread. The author reviewed results from other studies showing also reduced GIP responses to various grain products compared with white bread. Howarth et al. (2001) summarized that dietary fiber may have an effect on gut hormones, although the proposed mechanisms remained speculative. GLP-1 is released in response to glucose, fat, fermentable fiber and other stimuli and may slow gastric emptying and reduce hunger. In animal studies GLP-1 promoted weight loss when provided exogenously and it was proven that ingestion of dietary fiber promotes GLP-1 secretion.

Leptin is a peptide hormone, released from white adipose tissue, which promotes weight loss by two different mechanisms. It reduces appetite, and thus food intake, and at the same time increases energy expenditure. Many epidemiological studies have examined the correlation between the intake of food or nutrients and blood leptin concentration (Kuroda et al. 2010). Murakami et al. (2007) indicated that the intake of dietary fiber was inversely associated with leptin level in young Japanese women and a similar trend was found also in Western population studies. Dietary fiber was the only nutrient, where association with lower serum leptin concentrations was significant after adapting on confounding factors such as BMI. There was a strong positive correlation between leptin and BMI, what can suggest leptin resistance proved in obese individuals. Comparing different food groups, there has been reported an inverse correlation between intake of whole grains and leptin level in Western countries. On the other hand, serum leptin concentrations were not related to dietary patters in the US population in the study of Ganji et al. (2009) and no significant correlation was found out between leptin and dietary fiber by Wayne et al. (2008).

Among hormones, ghrelin plays an important role in the satiety mechanism and it has been proposed as a valid biomarker of satiety in the short and long term (Vitaglione et al. 2009). It is the only gut hormone known to stimulate appetite (Cummings 2006). Ghrelin is a peptide, released primarily by stomach and duodenum, but also by ileum, caecum and colon. Levels of circulating ghrelin are high during fasting and rapidly fall after a meal. They are thought to be regulated by both - nutritional signals (type and composition of macronutrients) and caloric intake (energy dose). The exact mechanisms, by which nutrients suppress ghrelin levels, are beginning to be elucidated (Delzenne et al. 2010). Among all nutrients, carbohydrates might be the most effective in suppressing postprandial ghrelin concentrations (seen after glucose intake, as well as after polysaccharides consumption). The effect of dietary fiber on postprandial ghrelin is not fully understood, because of a small number of conducted studies and fiber diversity. Some of these examples summarize Karhunen et al. (2008) in their review. Vitaglione et al. (2009) investigated the effect of barley β-glucans on short- term appetite, ghrelin and PYY levels in healthy subjects. Satiety effects of β-glucan were mediated by ghrelin and PYY, which has an opposite influence as ghrelin. Although it has been demonstrated, that dietary fiber may influence PYY response in the short term, the role of PYY as the biomarker of satiety needs to be confirmed.

To sum up, various changes in gut and adipocyte derived hormones can be observed in humans after injection of higher amounts of dietary fiber. However, no obvious mechanism can be derived explaining the exact associations (Weickert and Pfeifer 2008).

Other beneficial cereal components that may synergize the effect of dietary fiber

The beneficial effects associated with whole grain consumption are in part due to the existence of the unique phytochemicals of whole grains. The most important groups of phytochemicals found in whole grains can be classified as phenolics, carotenoids, vitamin E compounds, lignans, and β-glucan and inulin being part of dietary fiber (Liu 2007). Many of these compounds demonstrate strong antioxidant activity; others are effective in controlling blood sugar (β-glucan, inulin), lipoprotein profile (phytosterols) or as a prevention of cancer due to its hormonal effect (lignans) or possessing prebiotic qualities (inulin).

Cereal antioxidants from whole grain parts such as bran may also contribute to insulin sensitivity by protecting against oxidative stress. Hence high insulin levels may promote obesity by altering adipose tissue physiology (shunting metabolic fuels from oxidation to storage and increasing appetite); consumption of whole grains with insulin sensitizing effect may indirectly support body weight regulation (Koh-Banerjee and Rimm 2003). Epidemiological data confirm that consumption of whole grains improve insulin sensitivity and lower levels of serum insulin. The results from cohort study performed by Steffen, et al. (2003) showed that whole grain intake is associated with greater insulin sensitivity and lower BMI in adolescents, particularly among heaviest children in the study. These results are consistent also with studies of adults (Pereira et al. 2002). The synergistic effect of several whole-grain components (phytochemicals, vitamin E, Mg and dietary fiber or resistant starch) may be involved in the protective mechanism against diabetes and obesity (Slavin 2004).

Lignans are a group of dietary phytoestrogen compounds that comprise two coupled C_6C_3 units. When consumed, plant lignans are converted into mammalian lignans enterodiol and enterolactone by human intestinal microflora. Mammalian lignans have strong antioxidant activity and weak estrogenic activity what may account for their biological effects and health benefits such as protection against heart disease, hormone-related breast or prostate cancers (Liu 2007; Fardet et al. 2008).

Phytosterols is a collective term for plant sterols and stanols, which are similar in structures to cholesterol, differing only in the side chain groups. High intake of plant sterols or stanols can lower serum total and LDL cholesterol concentrations (Moghadasian and Frohlich 1999, Windler et al. 2008) and thus protect against atherosclerosis (Nashed et al. 2005). Phytosterols compete with cholesterol for micelle formation in the intestinal lumen and inhibit cholesterol absorption (Liu 2007). In addition, phytosterols also play an important role in cancer prevention.

Whole grain wheat contains about 3 % lipids and whole grain oat 7.5 %. Grain lipids are about 75 % unsaturated, comprised of nearly equal amounts of oleic and linoleic acid and 1-2 % of linolenic acid. Both these predominant fatty acids are known to reduce total and LDL serum cholesterol and are an important component of a heart- healthy diet (Slavin, 2003; Slavin 2004).

Conclusion

Epidemiological studies have shown that regular consumption of whole grain cereals leads to risk reduction of developing chronic diseases such as cardiovascular disease, type 2 diabetes, some types of cancer, obesity and all-cause mortality. Whole grain cereals are rich in many beneficial components such as dietary fiber, β-glucans, vitamins, minerals, lignans and phenolic compounds. The synergic effect of these substances might be responsible for the presented health benefits. Whole grain consumption seems to be an effective dietary strategy to prevent or treat overweight mainly due to dietary fiber content with its several biological mechanisms. Dietary fiber promotes satiation and satiety, alter glycaemic index, affects gastric emptying, gut hormone secretion and thus helps people to manage their weight. It is important to say that dietary fiber intake must not always have positive influence on health, an example are people with irritable bowel syndrome (IBS). Dietary fiber effect mechanism is not yet fully elucidated, because of a small number of conducted studies, where diverse fiber types showing various physical and chemical properties in different dosages are used. It would be wise to conduct long-term studies, where more sources of fibers with defined properties will be tested under the same conditions evaluating complete range of parameters to select the ideal fiber type for specific use in obesity and generally health prevention.

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