Effect of dietary fibre and protein on postprandial satiety and satiety peptides

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INTRODUCTION

Sensation of hunger and satiety are part of the complex network of neural and humoral factors that regulate energy homeostasis to balance energy needs with the supply (1). A number of central and peripheral hormones and peptides have been implicated in the regulation of food intake, serving as hunger and satiety signals (2,3). Also different foods, despite their equal energy content, can differ in their capacity to regulate energy homeostasis (4). This can be accounted for multiple characteristics of food, such as energy density, macro- and micronutrient composition, palatability, appearance, structure and requirements for mechanical processing.

DIETARY FIBRE

Among the multiple characteristics of food, dietary fibre in particular has been shown to be efficient in inducing satiety (5,6). The effects of different types of dietary fibres are distributed along the gastrointestinal tract producing the beneficial effects described in several comprehensive studies. Satiety producing effect of dietary fibre has been linked both to the decreased rate of gastric emptying as well as to the decreased rate of macronutrient absorption within the gastrointestinal tract thus increasing post-ingestion, pre- and post-absorptive satiety signals (7,8). At least part of the satiety effects of fibre are related to its viscosity producing property, a typical characteristic of various soluble fibres such as pectins and gums (8). Fibre also decreases energy density, and quite often, the palatability of the food, both of which can promote the satiety effects of the fibre as well. Also the requirements for mechanical processing (e.g. mastication) are greater after fibre-rich food, which enhances the amount of satiety signals arising from the mouth and other parts of the gastrointestinal tract. In addition to the positive effects of soluble dietary fibres on the upper part of the gastrointestinal tract, soluble fibres have also been shown to benefit the gut microflora in the lower part of the GI -track, especially in the colon inducing fibre stimulated fermentation and thereby well-being of the microflora. Consequently, colonic fermentation has also received an increasing attention as a potential factor inducing fibre-related satiety, but this remains speculative (9). Insoluble dietary fibres such as cellulose, some hemicelluloses and lignins have also favourable effects on the lower part of the gastrointestinal tract serving almost exclusively as bulking agents that result in shorter faecal transit time and increased intracolonic mass. However, satiety producing effects of pure insoluble fibres remain yet largely unidentified.

PROTEIN

Among different macronutrients protein has been shown to have the highest satiety value (10,11). Increasing dietary protein relative to carbohydrates and fat also enhances weight loss. However, the mechanisms explaining higher satiety value of protein are still poorly understood. One suggested mechanism is the greater dietary-induced thermogenesis associated with higher protein intake (11). Also monotony of the diet and ketosis may, at least partly, explain the effect of high-protein diets on reduced hunger and food intake (1). Recent preliminary evidence in animals has connected the satiating effect of protein also to intestinal gluconeogenesis (12). Higher satiety effect of protein may also be involved with the altered production of gastrointestinal satiety-related peptides (13), although contradictory results have also been reported (14,15).

SATIETY-RELATED PEPTIDES IN THE CONTROL OF FOOD INTAKE

Several centrally and peripherally produced and operating hormones and peptides have been implicated in the regulation of food intake primarily in short term. These peptides are secreted mainly by the gut in response to the different nutrients. Majority of these humoral signals are related to termination of the meals and hence are called satiety signals; these satiety promoting peptides / hormones include cholecystokinin (CCK), glucagon-like peptide 1 (GPL-1) and peptide YY (PYY), CCK being the most investigated. Yet a considerable number of other satiety inducing hormones have been identified though not included in this presentation. Only one peripherally secreted peptide hormone, ghrelin, has so far been identified to increase food intake and is therefore occasionally cited as a "hunger hormone". Thus, both satiety
promoting and hunger inducing signals operate in a complex manner to regulate short and long term food intake as well within central and peripheral systems.

**The effects of different dietary fibres on postprandial satiety peptides**

Little is known about the effects of dietary fibre on hunger- and satiety-related peptides. However, these effects seem to be fibre-specific and dependable on the amount ingested. When reviewing studies focusing on the effects of specific type of dietary fibre on satiogenic peptides only a limited number of studies was available. Moreover, majority of those had examined these effects when the fibre studied had been incorporated in meals with different structures and macronutrient contents. Different dietary fibres, including hydrolyzed guar gum, beta-glucan in barley pasta, fibre in bean flakes and fibre mostly from oatmeal and oat bran, when added to a mixed meal, have been shown to produce greater postprandial increases in CCK concentrations, as well as prolonged elevations of the hormone than low fibre meals or placebo (16-19). However, the differences in body mass index, sex and macronutrient composition of the meals may also have contributed to the responses. In a study conducted by Möhlig et al. (20) arabinoxylan enriched breakfast induced a shorter postprandial decrease in ghrelin when compared to a control breakfast. Instead Nedvidkova et al. (21) reported that a small amount (4 g) of psyllium, was as effective at suppressing total plasma ghrelin concentrations as a 585-kcal mixed meal. Blom et al. (22) reported a prolonged ghrelin suppression after high-calorie simple carbohydrate and high-calorie complex carbohydrate liquid meal compared to low-calorie meal. In a work of Grendel et al. (23) addition of carob fibre (5, 10 of 20 g) to a liquid meal did not affect the ghrelin response in comparison to a non-fibre meal. GLP-1 responses also vary according to the fibre type used. Adam and Westerterp-Plantenga reported elevated GLP-1 levels after the ingestion of a standard breakfast with additional galactose (50g) / guar gum (2.5 g) load compared to standard breakfast alone (24). According to a study by Raben et al. (25) GLP-1 concentrations were significantly reduced after a liquid meal supplemented with 50 g raw potato starch (54.1 percent resistant starch) contrasted with a meal of 50 g of pregelatinized potato starch (100 percent digestible). Furthermore, Juntunen et al. (26) demonstrated that GLP-1 responses, except for GLP-1 responses to the rye bread containing oat ß-glucan concentrate, were lower after the consumption of whole-kernel rye bread and whole-meal pasta than after consumption of white wheat bread.

Considering the relation among different types of dietary fibres and PYY, it is currently not known what, if any, impact dietary fibre has on PYY concentrations (27). Although different types of dietary fibres have been shown to enhance satiety as such or incorporated in various food compositions, there are undoubtedly also other elements involved in this multifaceted phenomenon, such as food matrix and the physical structure and state (solid, semisolid, liquid) of the component as well as the influence of other macronutrients.

**The effect of protein source on postprandial satiety peptides**

Although a substantial amount of evidence exists pertaining to the satiety inducing effects of protein there is still a relatively limited number of studies performed focusing on dietary protein and its effects on postprandial satiety-related peptides. In the study of Bowen et al. (28) CCK remained elevated after liquid protein preload (83 E percent, whey, casein) ingestion, which was associated with decreased appetite. Compared to carbohydrate, protein caused a prolonged suppression of ghrelin. In the subsequent study of Bowen et al. (29) liquid protein preloads (71 E percent, whey, soy, gluten) prolonged the postprandial suppression of ghrelin and elevation of GLP-1 and CCK when compared to glucose preload alone. In addition, the postprandial changes after the protein preloads were similar and differed overall from the glucose treatment. Moran et al. (30) and Lejeune et al. (31) reported no difference in ghrelin secretion between high- or standard-protein meals. Instead, Erdmann et al. (32) detected an increase in ghrelin secretion after protein test meal (pork meat 83 E percent prot, 17 E percent fat), whereas carbohydrate caused ghrelin suppression. There were no differences in appetite ratings between the test meals. However, energy intake from the carbohydrate meal was almost double compared to the protein meal. Also in an earlier study of Erdmann et al. (33) protein (turkey 99 E percent prot) stimulated ghrelin secretion. In a study conducted by Blom et al. (34) a high-protein test meal (a dairy product enriched with whey protein isolate 58.1 E% prot) suppressed ghrelin, reduced the rate of gastric emptying and stimulated CCK and GLP-1 secretion more than did a high-carbohydrate meal. Despite these differences in satiety-related peptides, subjective sensations of hunger and ad libitum energy intake during lunch were not significantly different between the meals. CCK and GLP-1 responses were also investigated in a study by Hall et al. (35) in which CCK level was increased by 60 percent and GLP-1 by 65 percent following the whey preload compared with the casein. Whey was also more satiating that casein (35). GLP-1 responses were also the highest after a protein rich meal (crisp bread with cheese, yoghurt with muesli, egg, and skim milk 32 E% prot) in a study performed by Raben et al. (36). Moreover, CCK secretion after protein load was significantly greater than that found after ingestion of starch (37). Studies focusing on the effects of different dietary proteins on PYY are limited. In a study conducted by Pedersen-Bjergaard et al. (38) it was found that protein-rich meals produced the highest postprandial PYY concentrations. Calbet and Holst demonstrated that different protein solutions of similar caloric density (whey or casein whole protein, whey or casein hydrolysate) elicited a similar PYY response hardly influenced by the degree of fractionation or the amino acidic composition (39). Moreover, Sanggaard et al. showed that ingestion of fermented milk resulted in a slightly greater increase in PYY concentrations compared with whole milk in the initial part of the study period, but there was a crossover, after which the whole milk meal resulted in higher PYY concentrations than the fermented milk in the latter part of the study (40). Thus, despite the intensive research, the relation among satiety-related peptides, subjective hunger and satiety and varied protein sources remain inconsistent, and there obviously are other, distinct and/or synergetic, mechanisms involved. In addition, it seems that there might also be differences in the satiating properties of different protein sources, possibly related to factors influencing protein digestion, absorption and postprandial excursions in circulating amino acids concentrations (35). Indeed, different protein sources, such as fish, beef and chicken, have elicited varied satiety responses, fish being the most satiating source among them (41). Nevertheless, the differences in the satiating properties of different protein sources have not been seen in all studies (42).

**CONCLUSION**

Taken together, dietary protein and fibre have been demonstrated to enhance satiety and satiety-related mechanisms. Although our understanding of the satiogenic effects of different dietary fibre and protein sources and the effects of these components on satiogenic peptides wait for further clarification and consolidation, the existing knowledge lends support to beneficial effects of dietary fibre and protein on the modulation of hunger and satiety sensations. Thus, these dietary compounds may provide the urgently needed tools.
to prevent weight gain in the population level and offer readily accessible and familiar components to the daily diet for the individuals especially concerned with weight management and overall well-being.

REFERENCES AND NOTES


