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Functional foods for weight management: Dietary Fiber – a systematic review

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ABSTRACT

It has been estimated that more than 1.5 billion adults are overweight or obese worldwide [1], rendering obesity a global epidemic [2]. Obesity is associated with significant morbidity, including type 2 diabetes, cardiovascular disease, osteoarthritis and some cancers [3]. Thus, obesity is clearly a medical issue, its costs impacting heavily on health care systems in both developed and developing nations [4]. The combined impact of transmissible and chronic disease in the third world is particularly devastating to the very health care systems with fewest resources [5].

Because obesity has been identified as a major health issue, treating obesity is an important goal. However, weight loss management has proven notoriously difficult. It is well documented that reduced energy intake and increased energy expenditure may reduce body weight in the short term, but obesity relapse is the long term is anticipated [6]. In a study of overweight or obese US adults who weighed ≥ 10% less than their maximum body weight the year prior to the survey (n=1310), 33.5% regained > 5% during that year [7].

Despite its somewhat unimpressive success rate, "lifestyle" weight management remains the first line intervention for obesity treatment [8]. Lifestyle weight management can be defined as interventions based on energy restriction (weight loss diet); increased energy output (exercise); and/or behavioral change (cognitive or behavior therapy). Functional foods have been explored as a tool for enhancing lifestyle weight management.

Functional foods evaluated for their efficacy as obesity interventions can be divided into two broad categories: 1) foods which suppress appetite and increase satiety; and 2) foods which enhance thermogenesis. The present review will focus on those foods thought to act by increasing satiety and suppressing appetite.

Key words: Obesity, weight loss, systematic review, dietary fiber

FOODS WHICH ACT ON APPETITE – DIETARY FIBER

Dietary fiber can be defined as non-digestible carbohydrates with a degree of polymerization ≥3 [10]. Additionally, a list of beneficial physiological effects of dietary fiber was developed including reduction in blood total and/or LDL cholesterol; attenuation of postprandial blood glucose and/or insulin levels; increased stool bulk and/or decreased transit time; and fermentation by colon microflora. It is noteworthy that additional fiber attributes, such as weight loss/reduced adiposity and increased satiety were not included in the list of beneficial effects [11].

Dietary fiber is not a uniform entity, but rather diverse group of polysaccharides including resistant starch, other glucose polymers with alpha or beta linkages, polymers based on specific sugars such as pectins, fructans and xylans; fiber of marine origin such as alginate and chitosan; and complex fibers rich in pectin, arabinoxylan or beta glucan. Additionally, each of these dietary fibers may be further classified by physiochemical properties including fermentability, solubility and viscosity [12].

One goal of incorporating functional foods into weight management is to enhance satiety and inhibit appetite. Logically, this should reduce food intake and ultimately result in weight loss. Dietary fibers of various types and sources have been proposed as a means through which these weight management goals may be achieved. A systematic review of clinical trials evaluating the impact of dietary fiber interventions on appetite, satiety, energy intake and body weight enables an estimation of its true efficacy.

METHODS

The association between dietary fiber of any kind and outcomes including satiety, appetite, body weight and/or energy consumption was evaluated by examining clinical trials published during the last two years, from 2010-2012. Search terms included dietary fiber, clinical trial, appetite, and their synonyms. The search was limited by year (2010-2012). Only studies conducted in adults were included.

RESULTS

A total of 15 studies met the inclusion criteria. Table 1 summarizes the findings. Overall, studies had small sample size and only five (33.3%) included overweight/obese subjects. Five of the studies measured outcomes 30 min- 8 hours post exposure [13, 14, 19, 20, 23]. Four studies examined outcomes 24 hours past exposure (15, 22, 24, 27), and six studies had longer duration, from 2-15 weeks past exposure [16-18, 21, 25, 26].

Satiety and appetite were evaluated in 10 of the 15 studies (66.6%) studies. Of these, 7/10 reported significantly enhanced satiety and 6/10 reported significantly reduced appetite in the fiber intervention compared to the study) control.

Ten of the 15 studies evaluated energy intake. Energy intake was examined in four of the five short term studies, all of which reported a significant reduction in energy intake [13, 14, 19, 23]. All of the 24-hour studies examined energy intake. Two reported reduced dietary intake following fiber exposure [15, 27], one reported no effect on dietary intake [24], and another reported reduced intake in women but increased intake in men [22]. Of the six longer duration studies, two examined energy intake [17, 26], neither of which detected a reduction in energy intake by fiber exposure. The association between duration of fiber exposure and proportion of exposed subjects with reduced energy intake is presented in Figure 1.

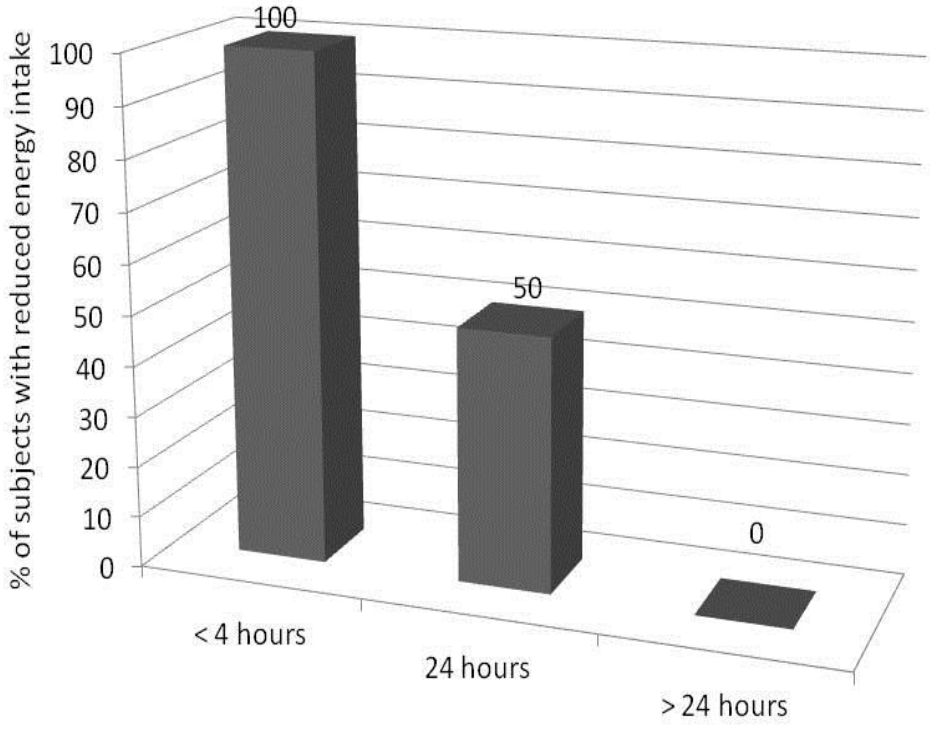
Table 1. Summary of Studies

Author	Fiber	Control	Subjects	Study Duration	Satiety	Appetite	Energy intake	Body Weight
Smith et al. 2012 (13)	Yellow pea fiber	Yellow pea protein	Healthy males (n=19 experiment 1; n=20 experiment 2)	30 min (experiment 1); 120 min (experiment 2)	N/A	No effect	Protein reduced 30 min food intake vs. fiber; no effect at 120 min	N/A
Ibrugger et al. 2012 (14)	Flax fiber drink (exp. 1)or tablets (exp 2)	Isocaloric/isovolumeric drink without fiber	Healthy subjects (n=24 for experiment 1, n=20 for experiment 2)	120 min	Flax drink increased satiety vs. control	Flax drink and flax tablets reduced appetite vs. control	Flax drink reduced subsequent energy intake	N/A
Barone et al. 2012 (15)	ß-glucan or dietary fiber from fruit	Beverage with no fiber	Healthy volunteers (n=14)	24 hours	Reduced by both types of fiber vs. control	Reduced by both types of fiber vs. control	Intake reduced by ß-glucan vs. control	N/A
Jensen et al. 2012 (16)	Low viscous alginate	Hypo-caloric diet with placebo supplement	Obese subjects (n=96)	12 weeks	N/A	N/A	N/A	No effect
Isaksson et al. 2012 (17)	Whole grain rye	Refined wheat	Healthy subjects (n=24)	Two, 3-week phases (crossover design)	Whole grain rye increased satiety vs. refined wheat	Whole grain rye decreased appetite vs. refined wheat	No effect	N/A
Jensen et al. 2011 (18)	Low viscous alginate	Hypo-caloric diet with no supplement	Obese adults (n=24)	Two weeks	N/A	N/A	N/A	No effect
Calame et al. 2011 (19)	Two different blends of gum arabic dissolved in water	Water	Healthy volunteers (n=54)	3 hours	Both blends increased satiety vs. control	N/A	Both blends reduced intake vs. control	N/A

Isaksson et al. 2011 (20)	Rye kernels or mille rye prepared as bread (exp 1); or as porridge (exp 2)	Sifted wheat bread	Healthy volunteers (n=24 for experiment 1; n=20 for experiment 2)	8 hours	Whole and milled rye increased satiety vs. control	Whole and milled rye decreased appetite vs. control	N/A	N/A
Lyon et al. 2011 (21)	High viscosity polysaccharide	Inulin	Non-dieting overweight or obese adults (n=29 intervention; n=30 control)	15 weeks	N/A	N/A	N/A	Weight loss greater in intervention group in women
Hess et al. 2011 (22)	Short chain fructooligosaccharides (5 or 8 g) as beverage (dose1) and 5 or 8 g as chew (dose 2)	Beverage not containing fiber (dose 1); Chew without fiber (dose 2)	Healthy volunteers (n=20)	24 hours	No difference intervention vs. control	No difference intervention vs. control	No difference 5 g vs. control; 8 g vs. control reduced intake in women; increased intake in men	N/A
Monsivais et al. 2011 (23)	12 g soluble fiber dextrin or 11.8 g corn fiber or 11.8g polydextrose or 11.2 g resistant starch	Isoenergetic low fiber control or lower energy, low fiber control	Healthy adults (n=36)	4 hours	All fibers enhanced satiety more than low energy-low fiber control; no difference from isoenergetic-low fiber control	All fibers reduced appetite more than low energy-low fiber control; no difference from isoenergetic-low fiber control	Soluble fiber dextrin significantly reduced energy intake at next meal vs. isoenergetic low fiber control	N/A

Juvonen et al. 2011 (24)	10 g wheat bran; 10 g oat bran; 5 g wheat bran + 5 g oat bran presented in pudding	Pudding with no added fiber	Normal weight adults (n=20)	24 hours	No difference by exposure	No difference by exposure	No difference by exposure	N/A
Guerin-Deremaux et al. 2011 (25)	Soluble dextrin fiber Nutriose in 8, 14, 18 or 24 g/d dose in orange juice	17 g maltodextrin in orange juice	100 overweight healthy Chinese adults (n=20 per group)	3 weeks	Immediate increase in satiety for 14, 18 and 24 g dose; increased satiety from day 5 for 8 g dose	Reduced appetite from day 5 for 24 g dose and from day 7 for 14 and 18 g dose	N/A	N/A
Beck et al. 2010 (26)	5-6 g or 8-9 g oat beta glucan/day	Energy deficit diet with no added fiber	Overweight women (n=66)	3 months	N/A	N/A	No difference between groups	No difference between groups
Bodinham et al. 2010 (27)	48 g resistant starch + 32 g rapidly digestible starch	32 g rapidly digestible starch	Healthy males (n=20)	24 hours on two separate occasions	No difference between groups	No difference between groups	Resistant starch significantly reduced energy intake	N/A

Fig. 1 Proportion of subjects with reduced energy intake by duration of fiber intervention



Nine studies examined both satiety/appetite and energy intake [13-15, 17, 19, 22-24, 27], all of which were conducted in healthy, normal weight adults. Four of these studies [14, 15, 19, 23] reported that dietary fiber enhanced satiety/diminished appetite and reduced energy intake; however, one study did not observe a reduction in energy intake despite decreased appetite [17]. Four studies did not observe a difference in satiety/appetite between subjects consuming dietary fiber vs. controls, one of which found no concomitant reduction in energy intake [24]. One study observed reduced energy intake at 30 min but not 120 min past fiber exposure [13]. Another study reported no change in energy intake with lower dose fiber (5g), but at the higher dose (8g), women exhibited reduced energy intake while men increased energy intake [22]. Finally, one study reported reduced energy intake despite no change in satiety/appetite [27].

Body weight was evaluated as an endpoint in four of the 15 studies, all conducted in overweight/obese subjects. Three of these [16, 18, 26] found that dietary fiber had no effect on body weight compared to placebo, while one study found improved weight loss in women but not in men [21].

DISCUSSION

Dietary fiber intake is inversely associated with cardiovascular disease, type 2 diabetes, overweight and obesity, metabolic syndrome and its components, as well as gastrointestinal

diseases [28]. Indeed, viscous dietary fibers have been shown to dampen the post prandial glucose response, reduce total and low density lipoprotein cholesterol, and promote laxation [29].

Mechanisms through which dietary fiber is believed to facilitate weight management include enhancement of satiation and suppression of between-meal appetite [30]. Dietary fiber may influence appetite through the characteristics it imparts to food and also through physiologic effects in the individual. For example, high fiber foods may provide bulk, leading to gastric distention, which creates a sense of satiety [31]. Consistent with this, enhanced satiety and/or reduced appetite were in fact identified in most of the studies measuring this outcome [14, 15, 17, 19, 20, 23, 25]. It is noteworthy that only one of these studies [25] was conducted in overweight patients. All four studies in which dietary fiber was not associated with satiety/appetite were conducted in healthy, normal weight subjects [13, 22, 24, 27].

To contribute to weight management, enhanced satiety/reduced appetite should be associated with reduced energy intake. Nine studies measured both satiety/appetite and energy intake. Five of these reported enhanced satiety/reduced appetite in the fiber group, and four of these five observed concomitant reduction in energy intake [14, 15, 19, 23]. Four studies did not observe satiety enhancement/appetite reduction, and not surprisingly, decreased energy intake was not recorded [13, 22, 24]. Interestingly, one study detected decreased energy intake at the post exposure test meal and for the next 24 hours despite no change in satiety/appetite [27]. The 24-hour energy reduction was driven by reduced fat intake, though no change in desire for fatty foods was indicated by participants on questionnaires.

CONCLUSIONS

Dietary fiber appears to enhance satiety and reduce appetite, but this is not consistently associated with reduced energy intake, particularly in the long term. Most of the studies evaluated were conducted in normal weight individuals. There is a need for well-designed randomized, controlled clinical trials in overweight and/or obese individuals in order to assess the efficacy of dietary fiber as a weight loss strategy.

Competing Interests

The present study received no funding and all authors declare that they have no competing interests.

Author Contributions

MB conceived of the study, reviewed articles for inclusion, conducted the analyses and wrote the manuscript. EL and JW reviewed articles for inclusion, edited the manuscript and approved the final version of the paper.

REFERENCES

1. Nguyen T, Lau DC. The obesity epidemic and its impact on hypertension. Can J Cardiol 2012; 28:326-33.

2. Ginter E, Simko V. Type 2 diabetes mellitus, pandemic in 21st century. Adv Exp Med Biol 2012; 771:42-50.
3. Pi-Sunyer X. The medical risks of obesity. Postgrad Med 2009; 121: 21-33.
4. Magnusson RS. Rethinking global health challenges: towards a 'global compact' for reducing the burden of chronic disease. Public Health 2009; 123:265-74.
5. Borch-Johnsen K. The metabolic syndrome in a global perspective. The public health impact--secondary publication. Dan Med Bull 2007;
6. Kissler HJ, Settmacher U. Bariatric surgery to treat obesity. Semin Nephrol 2013; 33: 75-89.
7. Sumithran P, Proietto J. The defence of body weight: a physiological basis for weight regain after weight loss. Clin Sci (Lond) 2013; 124:231-41.
8. Weiss EC, Galuska DA, Kettel Khan L, Gillespie C, Serdula MK. Weight regain in U.S. adults who experienced substantial weight loss, 1999-2002. Am J Prev Med 2007; 33:34-40.
9. Hainer V, Hainerová IA. Do we need anti-obesity drugs? Diabetes Metab Res Rev 2012; 28 Suppl 2:8-20.
10. Jones JM. Dietary fiber future directions: integrating new definitions and findings to inform nutrition research and communication. Adv Nutr 2013; 4:8-15.
11. Howlett JF, Betteridge VA, Champ M, Craig SA, Meheust A, Jones JM. The definition of dietary fiber - discussions at the Ninth Vahouny Fiber Symposium: building scientific agreement. Food Nutr Res. 2010 Nov 1;54.
12. Wanders AJ, van den Borne JJGC, de Graaf C, Hulshof T, Jonathan MC, Kristensen M, Mars M, Schols HA, Feskens EJM. Effects of dietary fibre on subjective appetite, energy intake and body weight: a systematic review of randomized controlled trials. Obesity Rev 2011; 12: 724-39.
13. Smith CE, Mollard RC, Luhovyy BL, Anderson GH. The effect of yellow pea protein and fibre on short-term food intake, subjective appetite and glycaemic response in healthy young men. Br J Nutr 2012;108 Suppl 1: S74-80.
14. Ibrügger S, Kristensen M, Mikkelsen MS, Astrup A. Flaxseed dietary fiber supplements for suppression of appetite and food intake. Appetite. 2012; 58: 490-5.
15. Barone Lumaga R, Azzali D, Fogliano V, Scalfi L, Vitaglione P. Sugar and dietary fibre composition influence, by different hormonal response, the satiating capacity of a fruit-based and a β-glucan-enriched beverage. Food Funct 2012; 3: 67-75.
16. Georg Jensen M, Kristensen M, Astrup A. Effect of alginate supplementation on weight loss in obese subjects completing a 12-wk energy-restricted diet: a randomized controlled trial. Am J Clin Nutr 2012; 96:5-13.
17. Isaksson Isaksson H, Tillander I, Andersson R, Olsson J, Fredriksson H, Webb DL, Åman P. Whole grain rye breakfast - sustained satiety during three weeks of regular consumption. Physiol Behav 2012; 105: 877-84.
18. Jensen GM, Kristensen M, Astrup A. Can alginate-based preloads increase weight loss beyond calorie restriction? A pilot study in obese individuals. Appetite 2011; 57: 601-4.

19. Calame W, Thomassen F, Hull S, Viebke C, Siemensma AD. Evaluation of satiety enhancement, including compensation, by blends of gum arabic. A methodological approach. Appetite 2011; 57: 358-64.
20. Isaksson H, Rakha A, Andersson R, Fredriksson H, Olsson J, Aman P. Rye kernel breakfast increases satiety in the afternoon - an effect of food structure. Nutr J 2011; 10:31-41.
21. Lyon M, Wood S, Pelletier X, Donazzolo Y, Gahler R, Bellisle F. Effects of a 3-month supplementation with a novel soluble highly viscous polysaccharide on anthropometry and blood lipids in nondieting overweight or obese adults. J Hum Nutr Diet 2011; 24: 351-9.
22. Hess JR, Birkett AM, Thomas W, Slavin JL. Effects of short-chain fructooligosaccharides on satiety responses in healthy men and women. Appetite 2011; 56: 128-34.
23. Monsivais P, Carter BE, Christiansen M, Perrigue MM, Drewnowski A. Soluble fiber dextrin enhances the satiating power of beverages. Appetite 2011; 56:9-14.
24. Juvonen KR, Salmenkallio-Marttila M, Lyly M, Liukkonen KH, Lähteenmäki L, Laaksonen DE, Uusitupa MI, Herzig KH, Poutanen KS, Karhunen LJ. Semisolid meal enriched in oat bran decreases plasma glucose and insulin levels, but does not change gastrointestinal peptide responses or short-term appetite in healthy subjects. Nutr Metab Cardiovasc Dis 2011; 21: 748-56.
25. Guérin-Deremaux L, Pochat M, Reifer C, Wils D, Cho S, Miller LE. The soluble fiber NUTRIOSE induces a dose-dependent beneficial impact on satiety over time in humans. Nutr Res 2011; 31:665-72.
26. Beck EJ, Tapsell LC, Batterham MJ, Tosh SM, Huang XF. Oat beta-glucan supplementation does not enhance the effectiveness of an energy-restricted diet in overweight women. Br J Nutr 2010; 103:1212-22.
27. Bodinham CL, Frost GS, Robertson MD. Acute ingestion of resistant starch reduces food intake in healthy adults. Br J Nutr 2010; 103:917-22.
28. Timm D, Slavin J. Dietary fiber and the relationship to chronic diseases. Am J Lifestyle Med 2008; 2: 233-40.
29. Chutkan R, Fahey G, Wright WL, McRorie J. Viscous versus nonviscous soluble fiber supplements: mechanisms and evidence for fiber-specific health benefits. J Am Acac Nurse Pract 2012; 24: 476-87.
30. Halford JCG, Boyland EJ, Blundell JE, Kirkham TC, Harrold JA. Pharmacological management of appetite expression in obesity. Nat Rev Endocrinol 2010; 6: 255-69.
31. Dikerman C, Fahey G. Viscosity as related to dietary fiber: a review. Crit Rev Food Sci Nutr 2006; 46: 649-63.