# Human Nutrition and Metabolism
## Research Communication

# Fermentable and Nonfermentable Fiber Supplements Did Not Alter Hunger, Satiety or Body Weight in a Pilot Study of Men and Women Consuming Self-Selected Diets[1,2]

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**ABSTRACT** Little is known about the relative effects of fermentable fiber (FF) vs. nonfermentable fiber (NFF) on energy regulation in humans. We compared $27 \pm 0.6$ g/d supplements of FF (pectin, $\beta$-glucan) and NFF (methylcellulose) for their ability to decrease ad libitum energy intake (EI) and hunger, increase satiety and cause spontaneous body weight and fat losses. Men and women ($n = 11$) aged 23–46 y, BMI 20.0–34.4 kg/m$^2$, consumed first NFF and then FF for 3 wk each, with a 4-wk washout period between phases. Daily satiety assessed with analog scales was higher with NFF than FF ($60.7 \pm 1.0$ vs. $57.7 \pm 0.8$ mm, $P = 0.01$). However, there were no differences in reported EI (NFF < FF by 7%, $P = 0.31$, NFF < baseline by 9.5%, $P = 0.11$), body weight (NFF 0.13 kg, $P = 0.73$; FF 0.13 kg, $P = 0.60$) or fat percentage (NFF −0.3%, $P = 0.56$; FF −0.1%, $P = 0.66$) within either phase. In contrast to findings in animals, NFF was more, rather than less satiating than FF, and use of neither NFF nor FF preparations was associated with body weight or fat loss. These pilot results suggest no role for short-term use of FF and NFF supplements in promoting weight loss in humans consuming a diet ad libitum. J. Nutr. 133: 3141–3144, 2003.

The new Dietary Reference Intake (DRI)[4] Adequate Intakes (AI) for fiber, 25 g/d for women and 38 g/d for men, are approximately twice the mean reported adult intake (1,2). Thus, substantial dietary changes are required to meet estimated needs, such as substituting whole grains, beans, fruits and vegetables for refined carbohydrates, or increasing fiber supplements of the type defined in the DRI as "functional" (i.e., those fiber isolates that have beneficial effects equivalent to those of dietary fiber from intact plant sources) (1). However, as recognized in the DRI recommendations (1), the relative benefits of consuming different types of fibers to meet the AI are not well understood, and further research on the optimal balance of different types of fibers is warranted.

One potential effect of an almost doubling of dietary fiber intake may be an increase in satiety and a reduction in energy intake, effects that could beneficially affect the current high prevalence of obesity (3). However, very few studies to date have directly compared different types of fiber for their effects on energy regulation; in particular, none have compared fermentable fiber (FF) with nonfermentable fiber (NFF). Thus it is not known whether various types of fibers influence energy regulation to different extents. Animal studies suggest that consumption of FF might enhance satiety to a greater extent than NFF, thereby resulting in greater reductions in energy intake and body fatness over time (4–7). Although the mechanisms that might be responsible for such effects are not fully understood, FF (but not NFF) stimulates the release of enteroglucagon (5) and stimulates proglucagon mRNA in the ilium of rats (6). Enteroglucagon is postranslationally processed into glucagon-like peptide-1 (GLP-1), an insulin secretagogue and putative satiety-inducing gut hormone (7). Consistent with these studies, intravenous infusion of GLP-1 in humans enhances satiety and decreases energy intake during the period of infusion (8–13). However, there is only one report comparing satiety in pectin- and methylcellulose-containing meals (14).

We therefore conducted a short-term, pilot study to examine whether consumption of supplements of FF would decrease hunger and energy intake, and promote weight loss, to a greater extent than NFF in free-living humans consuming food ad libitum.

## SUBJECTS AND METHODS

*Subjects.* The subjects were 11 healthy men ($n = 4$) and women ($n = 7$) aged 23–46 y (mean $30.7 \pm 7.3$) with mean weight $74.8 \pm 20.1$ kg, mean height $170.2 \pm 8.7$ cm, values for BMI ranging from 20.0 to 34.4 kg/m$^2$ (mean $25.5 \pm 5.0$) and mean percentage of body fat (%BF) $27.9 \pm 8.1$. They were recruited by local advertisement, and were free from acute or chronic diseases or use of medications that might influence study outcomes. A diet evaluation consisting of both a food-frequency questionnaire (15) and a 3-d diet record was

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obtained to identify and exclude individuals with a usual fiber intake >15 g/d. An Eating Inventory (16) was also administered to eliminate restrained eaters (defined as those scoring ≥12 on the restraint scale). Throughout the study, subjects lived at home and prepared their own meals, while consuming a fiber supplement provided by the investigators during the two 3-wk experimental phases. Subjects were instructed to eat until they were comfortably full and not consciously try to gain or lose weight. The protocol was approved by the Human Investigation Review Board at Tufts-New England Medical Center, and all subjects gave written, informed consent before participating.

*Protocol.* The study was a single-blinded, outpatient investigation consisting of two 3-wk phases (Phases 1 and 2) when a fiber supplement was consumed, with a 4-wk washout period between Phases 1 and 2. All subjects received the NFF supplement in Phase 1 and the FF supplement in Phase 2. This order was maintained because of the suspected potential for prolonged effects of the FF on GLP-1 secretion and resulting effects on food intake. In both phases, subjects were requested to increase fiber intake up to 30 g/d (or as close to that amount as comfortable) over the course of the first 3 d to minimize potential gastrointestinal upsets. Daily supplements (see below for formulation) were divided into three 10-g portions to be eaten 0.5 h before each meal with 12 fl oz (355 mL) of a noncaloric liquid, to achieve a maximum effect as a preload. The fiber supplements were provided by the Metabolic Research Unit of the Jean Mayer Human Nutrition Research Center on Aging at Tufts University. To assess compliance, subjects kept a log of daily fiber supplement consumption and returned the empty containers for weighing. They were instructed to consume the entire amount but if that was too difficult, to return the unconsumed portion so that the actual ingested amount could be calculated. Energy intake, hunger, satiety and body composition were measured at intervals during the study as described below.

The NFF was Methocel (Dow Chemical, Midland, MI), which is cellulose rendered fully soluble and nonfermentable by chemical alteration to hydroxypropyl methylcellulose (17,18) (Product Bulletin, Dow Chemical). The FF contained a 2:1 ratio of pectin (citrus peel extract; Danisco Cultor, New Century, KA) to β-glucan (oat extract; Saskatchewan Opportunities, Saskatoon, Canada), both of which are fully soluble and highly fermentable (19,20). To make the supplements, both fiber types were premixed with 75 g water and 3 g Crystal Light drink mix, heated and then congealed into gelatin-like puddings of similar consistency and palatability. Each serving contained <41.84 kJ.

*Reported energy intake.* Reported energy intake was determined by three unscheduled, interviewer-administered, 24-h recalls per phase (21,22). One recall was carried out each week during each phase (2 week days and 1 weekend day per phase) either in person or by telephone. Energy, macronutrient and fiber intakes were calculated using the University of Minnesota Nutrition Data System for Research (NDS-R), version 4.04, database 32 (Nutrition Coordinating Center, University of Minnesota, Minneapolis, MN).

*Anthropometry and body fatness.* Body weight was measured to the nearest ± 0.1 kg at the beginning, middle and end of each phase and the washout period; height was measured to ± 0.25 cm at the beginning of the study using a wall-mounted stadiometer. Body composition [percentage of body fat (%BF) and fat mass] was assessed at the beginning and end of each fiber phase by duplicate air displacement plethysmography assessments (BOD POD, Life Measurement, Concord, CA) using standard procedures (23).

*Hunger, satiety and adverse effects.* The frequency and severity of hunger and satiety and several potential adverse effects (thirst, nausea, diarrhea and constipation) were monitored each evening with 100-mm visual analog scales (VAS) (24). Hunger, satiety and thirst scales asked questions in the format "How frequently were you hungry today?" or "How severe were your feelings of hunger today?" and were anchored with the terms "much less than normal" and "much more than normal" at either end of the scale. Nausea and constipation scales asked how nauseous or constipated they felt that day, and were anchored by "not at all" and "extremely," and diarrhea by "not at all" and "4+ times" (25,26). To score the scale the distance in mm from 0 was measured with a ruler.

Hunger and satiety were also evaluated before and after administration of identical standard test meals (2090 kJ Ensure; Ross Products

Division, Abbott Laboratories, Abbott Park, IL) on the last day of each fiber phase. Comparison of these hunger and satiety sensations between the two test meals was made to assess the chronic effect of the two fiber supplements on postprandial values. Hunger, satiety, desire to eat and pleasantness of the meal were assessed with 100-mm VAS, before and at hourly intervals for 4 h after the test meal (other tests made more frequent administration unfeasible).

*Statistical analyses.* Paired Student's *t* tests were used to compare mean variables between Phase 1 and Phase 2. Repeated-measures ANOVA was performed to assess the effects of time (21 d) and fiber phase (NFF, FF) on outcome variables, using a Bonferroni adjustment for number of tests performed when post-hoc tests were significant. Associations of mean energy intake during each phase and change in energy intake from baseline with daily and postprandial hunger and satiety as well as with amounts of fiber supplement consumed were assessed by multiple regression analysis, controlling for body weight and %BF (which were not highly correlated; $r = 0.37$, $P = 0.26$) because fiber may be a more effective appetite suppressant in the obese (3). An α-level of 0.05 was used.

## RESULTS

The amounts of fiber supplements consumed did not differ between phases ($P = 0.10$) (**Table 1**). In both phases consumption of the fiber supplement increased total fiber intake (i.e., fiber supplement plus dietary fiber from the subjects' reported food) from 14.4 g/d, which was slightly below U.S. national reported mean of ~15 g/d (2), to ~43 g/d ($P < 0.001$). Dietary fiber intake from the subjects' reported food did not vary over time ($P = 0.66$ for Phase 1 vs. baseline, and $P = 0.80$ for Phase 2 vs. baseline).

There were no differences in reported 24-h energy intakes between baseline and Phase 1, baseline and Phase 2, or between Phases 1 and 2 (Table 1). However, energy intake (EI) tended to be lower (7%) during supplementation with NFF than during supplementation with FF ($P = 0.31$). In addition, EI tended to be lower (9.5%) during supplementation with NFF than at baseline ($P = 0.11$) Multiple regression analysis showed a positive association between the amount of FF supplement consumed per day and energy intake over the entire 3-wk period (partial correlation = 0.80, adjusted $R^2 = 0.632$, $P = 0.009$).

Daily values for frequency and severity of hunger, frequency and severity of satiety, thirst, constipation, nausea and diar-

## TABLE 1

*Fiber and dietary energy and macronutrient intakes (protein, carbohydrate, fat) in men and women during a prestudy baseline period and during 3-wk periods consuming a nonfermentable fiber (NFF) supplement and a fermentable fiber (FF) supplement[1]*

| | Baseline | Phase 1 (NFF) | Phase 2 (FF) |
|---|---|---|---|
| Fiber supplements | | | |
|   Nonfermentable, *g/d* | 0 ± 0 | 26.7 ± 0.7 | 0 ± 0 |
|   Fermentable, *g/d* | 0 ± 0 | 0 ± 0 | 27.5 ± 0.5 |
| Reported dietary intake | | | |
|   Energy, *MJ/d* | 8.5 ± 0.7 | 7.7 ± 0.5 | 8.2 ± 0.8 |
|   Protein, *% energy* | 16.4 ± 0.9 | 16.9 ± 0.8 | 16.4 ± 0.6 |
|   Carbohydrate, *% energy* | 52.4 ± 2.4 | 51.1 ± 2.1 | 49.8 ± 2.2 |
|   Fat, *% energy* | 28.9 ± 1.4 | 31.8 ± 1.7 | 31.7 ± 2.3 |
|   Dietary fiber, *g/d* | 14.4 ± 1.4 | 16.1 ± 1.7 | 15.6 ± 1.6 |
|   Total fiber, *g/d* (including supplements) | 14.4 ± 1.4[a] | 42.8 ± 2.3[b] | 43.2 ± 2.0[b] |

[1] Values are means ± SEM, *n* = 11. Means in a row without a common letter differ, $P < 0.001$.

rhea did not differ over time. Values for each variable in each phase over time were therefore calculated. Hunger ratings did not differ between fiber types (data not shown), but satiety ($P = 0.010$), thirst ($P < 0.001$) and constipation ($P < 0.001$) were all higher during NFF supplementation than during FF supplementation (**Fig. 1, Table 2**). Symptoms of nausea and diarrhea did not differ between the NFF and FF phases (Table 2).

Hunger and satiety responses to a standard test meal were also assessed to explore potential chronic effects of fiber supplementation (Table 2). Hunger significantly increased and satiety significantly decreased over the 4-h postprandial period in both phases, but there were no differences in these responses between phases (i.e., no difference between the phases in changes over time or in mean postprandial values at each time point, and no significant phase by time interactions) (data not shown).

Body weight and body composition varied only slightly over the 14 wk of the study. Subjects tended to gain weight (slightly >6 g/d) over each 21-d period (NFF $P = 0.73$, FF $P = 0.60$). Subjects tended to lose weight (11 g/d of fat) with NFF ($P = 0.55$) and tended to gain weight (4.6 g/d of fat) with FF ($P = 0.74$).

## DISCUSSION

Previous research has suggested that increasing total fiber intake up to recommended levels should reduce energy intake due to decreased hunger and/or increased satiety (3), which in turn should cause weight loss and a reduction in the current high prevalence of obesity and overweight (27). However, to
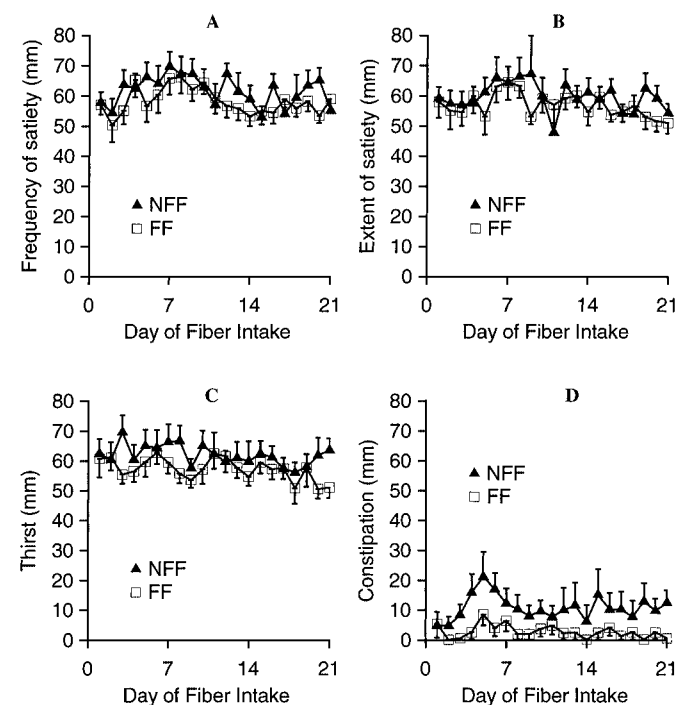


**FIGURE 1** Analog scale ratings in each fiber phase for daily satiety frequency (*A*), satiety severity (*B*), thirst (*C*) and constipation (*D*) in men and women during a 3-wk period of consuming a nonfermentable fiber (NFF) supplement and a fermentable fiber (FF) supplement. There were no trends over time for any rating, but differences between phases (NFF, nonfermentable fiber; FF, fermentable fiber, each given for 3 wk) were all significant at $P < 0.05$. Values are means ± SEM, $n = 11$.

### TABLE 2

*Daily and postprandial analog scale ratings for hunger, satiety and adverse effects in men and women during a 3-wk period of consuming a nonfermentable fiber (NFF) supplement and a fermentable fiber (FF) supplement[1]*

|  | Phase 1 (NFF) | Phase 2 (FF) | P-value |
|---|---|---|---|
| **Daily** | | | |
| Frequency of hunger | 41.3 ± 1.1 | 41.9 ± 1.0 | 0.679 |
| Severity of hunger | 39.7 ± 1.0 | 41.8 ± 0.8 | 0.073 |
| Mean frequency/ severity of hunger | 40.5 ± 1.0 | 41.8 ± 0.8 | 0.228 |
| Frequency of satiety | 61.7 ± 1.1 | 58.3 ± 1.0 | 0.005 |
| Extent of satiety | 59.7 ± 1.0 | 57.2 ± 0.9 | 0.053 |
| Mean frequency/extent of satiety | 60.7 ± 1.0 | 57.7 ± 0.8 | 0.010 |
| Severity of thirst | 62.0 ± 0.4 | 57.3 ± 0.8 | <0.001 |
| Severity of nausea | 4.0 ± 0.9 | 3.0 ± 0.7 | 0.277 |
| Severity of constipation | 10.7 ± 0.9 | 2.9 ± 0.5 | <0.001 |
| Frequency of diarrhea | 7.8 ± 1.4 | 10.1 ± 1.3 | 0.155 |
| **Postprandial** | | | |
| Severity of hunger | 43.8 ± 9.0 | 48.0 ± 6.5 | 0.344 |
| Extent of satiety | 39.4 ± 9.6 | 40.4 ± 6.4 | 0.822 |

[1] Values are means ± SEM for 100-mm analog scales, $n = 11$. Daily values were averaged over 21 d. Postprandial values were averaged over 4 h.

our knowledge, there is little information on the relative effects of different types of fibers on energy regulation. In this study, we found no differential effect of FF vs. NFF on energy intake or changes in body fatness over time when fiber intakes were increased from a mean of 15 to 43 g/d by supplementation with fiber isolates, suggesting similar effects of the two fibers on energy regulation. This finding was unexpected because consumption of FF increases GLP-1 secretion in animals (5,28), and GLP-1 is a putative satiety hormone causing weight loss in humans when administered exogenously at levels ranging from physiologic to supraphysiologic (8–13). Although the ~27 g/d of fiber supplement ingested by our subjects was likely to be at the upper end of what most human volunteers would be willing to consume, the dose may have been insufficient to influence gut hormones such as GLP-1 and cholecystokinin that may be affected by FF (5,28–30) and are putative satiety agents (8–13). Thus, on the basis of these results, it is reasonable to suggest no role for acceptable amounts of FF isolates in enhancing satiety and reducing energy intake in humans consuming a diet ad libitum.

Our results suggest that fiber supplements do not automatically have a beneficial influence on energy regulation, and that if they are to be effective, it would be under conditions different from those used in this study, perhaps when a longer duration was used, a larger number of more homogeneous subjects studied or under conditions of restricted energy intake. Despite the large total intakes of FF and NFF supplements, there were no significant changes in body weight or fat during consumption of either type of fiber, even among the subjects with higher BMI. It is conceivable that the specifics of our experimental design limited our ability to achieve a satiety effect. For example, the FF and NFF supplements were made palatable by dispersing them in flavored water, which may have prevented formation of the type of very viscous mixtures in the stomach that could have slowed gastric emptying (perhaps with greater effects on satiety). However, it should be noted that the fiber vehicles were as viscous as possible to be consistent with an acceptable supplement, and were not ad-

ministered in capsule form to avoid the possible risk of gastric blockage. The consumption of the supplements before, rather than during meals may have allowed the bulk of the supplement to exit the stomach before the meal was ingested. It is also possible that our use of fiber supplements rather than fiber in intact plants may have attenuated the natural slowing of gastric emptying by the fiber because the fibers were physically separated from the intact plant walls and other cellular structures that are associated with dietary fiber in most foods. In conclusion, contrary to expectations based on current theory concerning the gastrointestinal effects of FF, a large dose of FF was not more satiating or more effective at suppressing hunger than a similar dose of NFF when consumed for 3 wk. Furthermore, these relatively large doses of supplemental FF or NFF did not cause body weight or fat loss in this small population over a short period of time in human subjects spanning the body weight range from normal to obese. These results suggest no role for FF and NFF isolates in promoting negative energy balance in humans consuming a diet ad libitum.

## ACKNOWLEDGMENTS

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