Physiology & Behavior 147 (2015) 198–204

Contents lists available at ScienceDirect

Physiology & Behavior

journal homepage: www.elsevier.com/locate/phb

Long term ingestion of a preload containing fructo-oligosaccharide or guar gum decreases fat mass but not food intake in mice☆

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HIGHLIGHTS

- Fibers, regardless of type, inhibit food intake in short term intake.
- Fibers, regardless of type, lose its ability to inhibit food intake over time.
- Guar gum and fructo-oligosaccharide limit fat storage similarly in long term.

ARTICLE INFO

Article history:
Received 2 March 2015
Received in revised form 21 April 2015
Accepted 22 April 2015
Available online 24 April 2015

Keywords:
Fructo-oligosaccharide
Guar gum
Alginate
Food intake and adiposity

ABSTRACT

Fermentable dietary fibre such as fructo-oligosaccharide and viscous dietary fibers such as guar gum and alginate affect energy homeostasis. The goal of this study was to compare the impact of long term intake of these three dietary fibers on food intake, meal pattern, body weight and fat accumulation in mice. Over a period of 3 weeks, the mice were fed daily with a preload containing 32 mg of fructo-oligosaccharide or alginate or 13 mg of guar gum. Food intake and body weight were monitored weekly, while meal patterns, adiposity and the expression of hypothalamic neuropeptide genes were evaluated at the end of the study period. The 3 dietary fibers produced a similar decrease in total daily food intake (14 to 22%) at the end of the first week, and this effect disappeared over time. The 3 dietary fibers induced a slight variation in satiation parameters. Body weight and expression of hypothalamic neuropeptide genes were not affected by any of the treatment. Preload of fructo-oligosaccharide and guar gum induced a similar and substantial decrease in the development of adiposity (17% and 14%, respectively), while alginate had no effect. Our results demonstrate mainly that the inhibitory effect of dietary fiber on food intake is lost over time, and that guar gum limits fat storage.

1. Introduction

The two main properties characterizing dietary fibers, fermentability [1,2] and viscosity [3–5], affect energy intake [6–9], weight gain, fat accumulation and the lipid profile [8,10–14]. On the one hand, fermentable fibers such as fructo-oligosaccharide (FOS) have a potent short-term inhibitory effect on food intake and promote a decrease in body weight [15,16]. These effects of fermentable fibers are thought to be related to their modulation of gut microbiota and to the production of short chain fatty acids (SCFAs) which indirectly mediate their effects [17]. On the other hand, the viscous dietary fibers guar gum (GG) [18–21] and alginate (AL) [22–25] decrease energy intake and/or body weight for a limited time period (up to 1 week). For precision, two types of viscous fibers are identified: fibers that develop its viscosity outside the body, i.e. during its preparation, such as GG and those becoming viscous only during transit in the gastro-intestinal tract, such as AL. These 2 types of viscous dietary fibers slow down gastric emptying as well as peristaltism thereby increasing the anorexigenic and homeostatic signaling emanating from the gastro-intestinal tract [5].

Abbreviations: AL, alginate; FOS, fructo-oligosaccharide; GG, guar gum; BW, body weight.

☆ This project is supported by AgroParisTech and Institut National de la Recherche Agronomique (INRA, France).

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http://dx.doi.org/10.1016/j.physbeh.2015.04.039
0031-9384/

The hypothalamic neuropeptides such as the anorexigenic peptides pro-opiomelanocortin (POMC) and cocaine amphetamine regulatory peptide (CART), the orexigenic peptides agouti-related peptide (AgRP) and neuropeptide Y (NPY) [26–30] and the hypothalamic melanocortin-4 receptor [31,32] may be involved in the mechanism underlying the impact of all types of fibers on energy intake since they are well-known to take a prominent role in the control of energy homeostasis. Therefore, the short term effects of both fermentable and viscous dietary fibers on energy intake and fat storage are well described, however their impact over a longer time period (over 3 weeks) is less well characterized.

The aim of this study was to compare the impact of long term intake of the highly fermentable FOS and of the two types of viscous fibers, GG and AL [33] on food intake, eating behavior, body weight and fat accumulation in mice. Mice were fed each morning with a preload containing FOS, GG or AL for 3 weeks and had further access to a balanced diet over the following 7 h. Food intake, body weight and adiposity were monitored weekly. The meal pattern was analyzed at the end of the 3 week study period. We also measured the expression of genes in the hypothalamus for POMC/CART, NPY/AgRP and MC4R at the end of the 3-week study period.

2. Material and methods

2.1. Animals

Male C57BL/6J mice (Harlan Laboratories, Inc., Horst, The Netherlands), aged 8 weeks (20 to 25 g) at the beginning of the experiments, were housed individually in standard cages or in cages that allowed continuous recording of food intake. The cages were placed in a temperature- and humidity-controlled room (22 ± 1 °C, 53 ± 2% humidity) with a 12:12 light/dark cycle (lights off at 9:30). Throughout the study, the mice had access to food only during the dark period (between 9:30 and 18:00). The mice were fed with a preload from 9:30 a.m. to 10:00 a.m. and then had free access to NP, a modified AIN 93M diet containing 10% lipid, 14% protein and 76% carbohydrate in terms of energy with a proportion of 5% of dietary fibers (cellulose) [34,35], from 11:00 to 18:00 (7 h). The mice were adapted to the housing conditions, the food access period and handling for 7 days. During this period, no dietary fiber treatment was administered to the mice, as all of the groups were fed with the control preload C (without additional dietary fiber). The animals had *ad libitum* access to water. All of the experiments were approved by the local animal care and ethics committee (COMETHEA No. 11-004, 11-005, 11-006, 11-007, Jouy-en-Josas, France). Six to 7 mice each were assigned to one of the following groups: C (control group), FOS, GG or AL.

2.2. Fiber preloads

Each preload contained 32 mg of one of the dietary fibers, FOS, GG or AL (Sigma-Aldrich), mixed with the NP diet. The control preload (C) contained no additional dietary fiber. The energy provided by each preload was 5.02 kJ (or 1.2 kcal), which is equivalent to approximately 10% of the daily energy requirement for mice. The preload containing GG was very viscous and poorly accepted by mice at a dose of 32 mg, so the dose was reduced to 13 mg. The preloads were prepared the day prior to administration and stored at 4 °C. The preloads (Table 1) were administered to mice in solid form in free feeding. To test a dose that could be relevant for humans, we used a much lower dose of dietary fiber (1.28 g of fiber/kg body weight (BW)) than doses used in other rodent studies of food intake and body weight (5 to 10 g of fiber/kg BW) [16,36].

2.3. Food intake measurements and meal pattern analysis

When food intake was stable and similar between all of the groups (after a habituation period of 7 days), we began to administer dietary fiber to the mice. The food intake was measured manually by weighing the food cups at baseline and then weekly for the first 2 weeks of fiber intake. Food intake and meal patterns were assessed as follows: the dietary fiber preload was administered to mice from 9:30 to 10:00, and the mice were allowed to consume it freely. Intake of the NP diet was measured during the free-feeding period between 11:00 a.m. to 18:00, specifically at 12:00 (1 h of free-feeding), 14:00 (3 h of free-feeding), 17:00 (6 h of free-feeding) and 18:00 (total daily food intake). During the third week of dietary fiber treatment, the mice were housed in cages that allowed continuous recording of food intake for 3 days. The first 2 days served as the adaptation period, and the food intake was measured on the third day. The measurements were performed similar to previous studies [35,37], as follows:

(i) Food intake was recorded at 5 s intervals by continuous weighing of the food cups.
(ii) Custom data analysis software processed the changes in the weight of the food cup over time to determine the meal pattern, including: meal size (sensitivity <0.01 g), inter-meal interval (sensitivity 2 min) and speed of ingestion.
(iii) The feeding sequence was established based on feeding bouts, which were defined as feeding events lasting more than 10 s with an intake greater than 0.01 g.

The meal pattern for each animal was defined based on the following parameters: feeding bout number, bout size (g), bout duration (min), ingestion rate (g/min) and the inter-bout interval (min).

Table 1
Composition of the preloads. Each preload was prepared with fructo-oligosaccharide (FOS), guar gum (GG) or alginate (AL) incorporated in a standard NP diet and dissolved in water. The control preload (C) contained no additional dietary fiber. The C, FOS, GG and AL preloads were iso-caloric and had approximately equivalent weights.

	C	FOS	GG	AL
Diet (mg)				
NP diet[a]	344	344	344	344
FOS	–	32	–	–
AL	–	–	–	32
GG	–	–	13	–
Water	186	186	186	186
Total weight of preload	530	562	543	562
Energy density (kJ/g)	9.5	8.9	9.2	8.9

[a] The energy density of the NP diet is 14.6 kJ/g [34].

2.4. Body weight and adiposity measurements

The weight of mice was evaluated using a laboratory scale Sartorius Quintix 3102-1S (maximal capacity: 3100 g, reproducibility/standard variation: 0.01 g). Upon arrival, the mice were assigned randomly to one of the 4 groups. The mice in all of the groups had similar body weights at baseline, as the mean body weight of the mice in the C, FOS, GG and AL groups was 23.93 ± 0.42 g, 22.34 ± 0.42 g, 23.46 ± 0.45 g and 24.09 ± 0.58 g, respectively ($p > 0.05$).The mice were then weighed weekly during the fasting period (from 8:30 to 9:00).

The percentage of fat was evaluated by dual energy X-ray absorptiometry using a Lunar PIXImus densitometer (Lunar Corp, Madison, WI). The accuracy of this technique in measuring fat mass in mice has been extensively described previously [38]. This measurement was performed weekly at the same time in the afternoon (from 14:30 to 16:30). Mice were anesthetized with 1.5% isoflurane for the duration of the scan (15 min).