Appetite 57 (2011) 134–141

Contents lists available at ScienceDirect

Appetite

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

Research report

Influence of substrate oxidation on the reward system, no role of dietary fibre☆

Peio Touyarou [a], Claire Sulmont-Rossé [a], Sylvie Issanchou [a], Romain Despalins [b], Laurent Brondel [a,c,*]

[a] Centre des Sciences du Goût et de l'Alimentation, UMR 6265 CNRS, UMR 1324 INRA, Université de Bourgogne, Agrosup Dijon, 15 rue Hugues Picardet, 21000 Dijon, France
[b] CHU de Dijon, CIC-EC and INSERM CIE1, Dijon, France
[c] CHU de Dijon, Service d'Hépato-Gastroentérologie and UFR de médecine de l'Université de Bourgogne, Dijon, France

ARTICLE INFO

Article history:
Received 12 January 2011
Received in revised form 21 March 2011
Accepted 12 April 2011
Available online 21 April 2011

Keywords:
Dietary fibre
Food preferences
Metabolism
Reward system
Satiety

ABSTRACT

It has been suggested that a high intake of dietary fibre helps regulate energy intake and satiety. The present study aimed to examine whether dietary fibre influenced the liking and wanting components of the food reward system, the metabolic state or subsequent intake. Five sessions involving 32 normal-weight subjects (16 men and 16 women, 30.6 ± 7.6 year) were held. The sessions differed in the composition of the bread eaten during breakfasts (dietary fibre content varied from 2.4 to 12.8 g/100 g). Several factors such as the palatability, weight, volume, energy content and macronutrient composition of the breakfasts were adjusted. Energy expenditure, the respiratory quotient (R), olfactory liking for four foods, wanting for six other foods, and hunger sensations were evaluated before and after the breakfast, as well as before a morning snack. The results showed no significant differences after ingestion of the various breads. Interestingly, R correlated with olfactory liking and with wanting, which highlights in an original manner the influence of the metabolic state on hedonic sensations for food. In conclusion, dietary fibre was found to have no effect on olfactory liking and wanting, and had no detectable effect on satiety sensations or on subsequent energy intake.

Introduction

Today, overweight has reached epidemic proportions, with more than one billion adults concerned, 300 million of whom are clinically obese (WHO, 2006). Overweight results from a positive balance between energy intake and energy expenditure and increases the risk of a variety of comorbidities including type 2 diabetes, hypertension, dyslipidemia, and cardiovascular disease. Several studies point out the need to study food properties in order to positively influence physiological processes involved in the prevention and/or management of overweight (*e.g.* Riccardi, Capaldo, & Vaccaro, 2005).

Among functional foods (*i.e.* foods that have been shown to have physiological benefits or to reduce the risk of chronic disease, or both; Agriculture and Agri-Food Canada, 2009), dietary fibre (*i.e.* non digestible carbohydrates and lignin that are intrinsic and intact in plants; Institute of Medicine of the National Academies, 2001) may be of interest in the prevention and/or management of overweight (Anderson et al., 2009; Burton-Freeman, 2000; Howarth, Saltzman, & Roberts, 2001). Most studies already conducted on the question have reported either higher satiety or lower hunger with high-fibre diets than in low-fibre ones (*e.g.* Raben, Christensen, Madsen, Holst, & Astrup, 1994; Rigaud, Paycha, Meulemans, Merrouche, & Mignon, 1998). Other studies have shown a greater decrease in energy intake after the ingestion of high-fibre meals than of low-fibre ones (*e.g.* Delargy, Burley, O'Sullivan, Fletcher, & Blundell, 1995; Porikos & Hagamen, 1986). A decrease in body weight has also been observed after a high-fibre regimen in both normal weight (*e.g.* Tuomilehto, Voutilainen, Huttunen, Vinni, & Homan, 1980) and obese subjects (Walsh, Yaghoubian, & Behforooz, 1984). Finally, dietary fibre has been shown to enhance compliance with diets designed for weight loss (Astrup, Vrist, & Quaade, 1990; Birketvedt, Shimshi, Erling, & Florholmen, 2005; Pasman, Saris, Wauters, & Westerterp-Plantenga, 1997).

Fibre lowers energy density and sometimes diminishes the palatability of foods (Burton-Freeman, 2000), and several other mechanisms have been put forward to explain the lower hunger/energy intake following the ingestion of dietary fibre (Howarth et al., 2001; Tungland & Meyer, 2002). First, as regards the gastro-intestinal tract, dietary fibre increases chewing, which is thought to reduce the rate of ingestion (Heaton, 1973). It increases saliva and gastric juice production, and decreases gastric emptying, and

☆ Special thanks to Philip Bastable of the 'Pole de Recherche' of Dijon University Hospital for revising the English and to Pr Christine Binquet of the 'CIC-EC' of Dijon University and INSERM CIE1 for her advice for the statistic calculations. Supported by a grant from the French government under the FUI (*Fond Unique Interministériel*) through the project *Farine* + approved by the Pole de compétitivité VITAGORA. This study was conducted with the collaboration of Cerelab (Gustalis Sarl-France). The authors have no conflicts of interest and no financial disclosures related to this work.

* Corresponding author.
E-mail address: Laurent.brondel@u-bourgogne.fr (L. Brondel).

0195-6663/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.appet.2011.04.008

therefore increases gastric volume which activates satiation mechanisms (Norton, Anderson, & Hetherington, 2006; Rolls & Roe, 2002). It decreases nutrient absorption in the intestine and thus reduces the metabolisable energy from available food (Baer, Rumpler, Miles, & Fahey, 1997; Wisker, Maltz, & Feldheim, 1988). It slows transit time in the small bowel, possibly increasing the quantity of unabsorbed macronutrients in the intestine and therefore accentuating the "ileal brake" (Spiller et al., 1988). It triggers the secretion of GLP-1 (Reimer & McBurney, 1996), and as a result of bacterial fermentation in the colon, leads to the production of short-chain fatty acids (Hamer et al., 2008), implicated in satiety mechanisms. Second, concerning the blood compartment, dietary fibre is able to decrease the glycaemic index (for a review see Brennan, 2005), and the consumption of low glycaemic index foods may decrease subsequent food intake (Bornet, Jardy-Gennetier, Jacquet, & Stowell, 2007; Ludwig, 2000; Raben, 2002; Roberts, 2003) as well as bodyweight (Slavin, 2005). Third, as regards metabolism, dietary fibre may lower fat oxidation (Raben et al., 1994), but this effect remains controversial (Keogh, Lau, Noakes, Bowen, & Clifton, 2006).

While numerous studies have reported the satiating power of dietary fibre when added to a meal and its interest in the management/prevention of overweight, to our knowledge, the influence of dietary fibre on liking and on wanting (the two components of the reward system; Berridge, 1996; Berridge & Robinson, 2003), have not yet been investigated. Furthermore, the effect of dietary fibre on the substrate oxidation rate remains controversial. Therefore, the present study sought to investigate in humans the effect of dietary fibre on liking and wanting as well as on sensory-specific satiety (*i.e.* the drop in pleasantness aroused by the ingestion of a specific food; Rolls, Rolls, Rowe, & Sweeney, 1981), the substrate oxidation rate, and hunger and subsequent food intake, through five experimental crossover sessions. Five different breads with various amounts of dietary fibre were offered during breakfast, and the above parameters were measured during the morning. The hypothesis was that increasing the proportion of dietary fibre in the bread would decrease overall postprandial liking, wanting for test foods, hunger sensations, the respiratory quotient and subsequent food intake.

Materials and methods

Subjects

The participants were 32 volunteers, 16 males and 16 females, with a mean (±SD) body mass index of 22.0 ± 1.7 kg m^{-2} and a mean (±SD) age of 30.6 ± 7.6 years. Inclusion criteria were normal body weight (BMI between 19 and 25 kg m^{-2}) and good general health (as evaluated by a clinical examination). Exclusion criteria were: a high score in restriction (>9), hunger (>11), or disinhibition (>11), according to the Three Factors Eating Questionnaire (Stunkard & Messick, 1985); significant body weight variation (>10, p.100) during the previous six months; metabolic and allergic diseases; smoking habit (>5 cig/day); intense physical activity (>5 h/week); and any declared dislike for the foods offered.

The participants were invited to eat breakfast in the laboratory but were not informed about the aim of the study (they were told that the study concerned food choices after the consumption of breakfast). The protocol was approved by the ethics committee of Dijon, France (CPP-Est I) and written consent was given by all participants prior to the start of the study.

Sessions

Five sessions were held over five consecutive weeks (one session per week). Four sessions were balanced together (Williams's Latin square design). These sessions differed in the composition of the bread eaten during the breakfast. The bread was made with different flours with different dietary fibre contents. Two breads had high fibre content (HF1 and HF2) and the other two had low fibre content (LF and French baguette – FB). As the energy content and the macronutrient composition of the bread varied in the different sessions, butter and strawberry jam were added in order to minimise the differences in energy/macronutrient content and the palatability of the bread. A fifth session was added to evaluate the influence of the macronutrient composition of the bread *per se* independently of the dietary fibre content. For this purpose, more jam and less butter were spread on one of the high fibre breads (HF2), in order to increase its carbohydrate content and decrease its fat content. The fifth session ($HF2_{CHO+}$) took place one week before (for half of the subjects) or one week after (for the other half) the four balanced sessions.

Temporal sequence and general procedure

One week before the first session, the subjects had to fill in a food diary for 3 consecutive weekdays in order to evaluate their habitual energy intake during breakfast. All ingested foods (difference between initial and final weights) had to be carefully weighed (required accuracy: 1 g) and accurately reported by the subjects themselves. For this purpose, they were lent a digital balance (Page, Soehnle, Nassau, Germany).

The day before each session, the subjects had to avoid intense physical activity. They also had to ingest a standard meal for supper at home. This standard meal was composed of ravioli pasta (800 g), yoghurt (100 g) and apple compote (100 g). Subjects could consume as much ravioli as they liked during the first session but were encouraged to eat the same quantities before the following sessions and to eat the two desserts entirely. Supper took place between 19:00 and 21:00 (only water was allowed thereafter), and the participants had to go to bed before midnight.

On each test day, the subjects were asked to come to the laboratory by car or by bus (in order to avoid intense physical activity). Sessions started at 7:30, 7:50, or 8:10 according to the wishes of the subjects (always at the same time for each subject). Three subjects were tested on each test day with the staggered schedule. They were tested individually during completion of the questionnaire and for food intake but stayed together during the remaining periods.

The temporal sequence is presented in Fig. 1. After their arrival, the subjects rested on a bed for 10 min. Then, their energy expenditure (EE) and respiratory quotient (R) were calculated for 15 min (from t−20 to t−5). Afterwards, olfactory liking (OL) for four food items (see below), wanting (W) for six other foods items (see below) and hunger (H) were evaluated (from t−5 to t0). At t0 (*i.e.* at 8:00, 8:20, or 8:40), the breakfast, which comprised one of the bread types (HF1, HF2, LF, FB, or $HF2_{CHO+}$ according to the session) was eaten. Intake lasted less than 15 min. The pleasantness (P) of the bread eaten was evaluated for the first and the last mouthfuls; then OL, W and H were again evaluated.

During the following period (from t+20 to t+130), the subjects had to stay on a bed (only dozing, reading and listening to music were allowed). At t+45 and t+110, hunger sensations were re-evaluated and EE and R were subsequently calculated for 15–20 min (from t+130 to t+145). OL, W and H were then re-evaluated (from t+145 to t+150), as was the pleasantness of the bread eaten during the breakfast.

At t+150 (*i.e.* at 10:30, 10:50, or 11:10), a snack composed of an assortment of four kinds of sandwiches (with potted mince pork, butter, strawberry jam or honey) was offered. Visually, the appearances of the sandwiches were clearly different. The