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The influence of thermic effect of food on satiety

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Objectives: To evaluate energy expenditure after three isoenergetic meals of different nutrient composition and to establish the relationship between the thermic effect of food (TEF), subsequent energy intake from a test meal and satiety sensations related to consumption.
Design: The study employed a repeated measures design. Ten subjects received, in a randomized order, three meals of 2331 ± 36 kJ (557 ± 9 kcal). About 68% of energy from protein in the high protein meal (HP), 69% from carbohydrate in the high carbohydrate meal (HC) and 70% from fat in the high fat meal (HF).
Setting: The experiments were performed at the University of Milan.
Subjects: Ten normal body-weight healthy women.
Methods: Energy expenditure was measured by indirect calorimetric measurements, using an open-circuit ventilated-hood system; intake was assessed 7 h later by weighing the food consumed from a test meal and satiety sensations were rated by means of a satiety rating questionnaire.
Results: TEF was 261 ± 59, 92 ± 67 and 97 ± 71 kJ over 7 h after the HP, HC and HF meals, respectively. The HP meal was the most thermogenic ($P < 0.001$) and it determined the highest sensation of fullness ($P = 0.002$). There were no differences in the sensations and thermic effect between fat and carbohydrate meals. A significant relationship linked TEF to fullness sensation ($r = 0.41$, $P = 0.025$). Energy intake from the test meal was comparable after HP, HC and HF meals.
Conclusions: Our results suggest that TEF contributes to the satiating power of foods.
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Descriptors: thermic effect of food; satiety; food intake; nutrient composition

Introduction

The thermic effect of food (TEF), that is the energy required for digestion, absorption and disposal of ingested nutrients, is strongly influenced by the composition of the meal. Although it is widely accepted that protein consumption produces a greater TEF than isoenergetic amounts of either carbohydrate or fat (Robinson *et al*, 1990; LeBlanc *et al*, 1991), there are differing opinions on the TEF from carbohydrate and fat. Some authors find no differences (Welle *et al*, 1981; Kinabo & Durnin, 1990a,b) and others describe a greater expenditure of energy from carbohydrate intake (Glick *et al*, 1984).

The nutrient composition of the meal also influences the food intake and the physiological and psychological sensations associated with the consumption. Protein could be the most satiating macronutrient (Rolls *et al*, 1988; Barkeling *et al*, 1990; Hill & Blundell, 1990; Porrini *et al*, 1995a,b) whereas fat food seems to be appetising and less satiating than food rich in protein (Porrini *et al*, 1997), or in carbohydrate (Rogers, 1990; Blundell & Burley, 1991; Lawton *et al*, 1993). However, some studies differ in their results on the influence of macronutrients on hunger and satiety (Rolls *et al*, 1991; de Graaf *et al*, 1992) and as yet little is known.

What has emerged from literature is that protein is the most satiating and the most thermogenic nutrient, suggesting a relation between satiety and thermogenesis. On the other hand, the influence of fat and carbohydrate on both the phenomena is still unclear probably due to the fact that carbohydrate and fat consumption have a slightly different effect on satiety as well as on thermogenesis.

Brobeck (1985) suggested that the thermogenic potential of food is one of the most likely factors to offer a basis for quantitative control of food intake, however, in the last 10 y, only few studies have evaluated energy expenditure, food intake and satiety sensations at the same time (Raben *et al*, 1994; Stubbs *et al*, 1996). Raben *et al* (1994), investigating the effect of a high-fibre and an isoenergetic low-fibre meal on 6 h post-prandial thermogenesis and satiety, found that the high-fibre meal decreased TEF and fat oxidation but increased fullness compare with the low-fibre meal. Stubbs *et al* (1996) found that isoenergetically-dense high protein, high fat and high carbohydrate breakfasts led to similar 24 h energy expenditure but to detectable changes in hunger that were not of sufficient magnitude to influence subsequent intake.

The purpose of this research was to study the effects of meals rich in protein or carbohydrate or fat on thermogenesis, subsequent food intake and satiety sensations, and to analyse if there was a link between thermogenesis and eating behaviour.

Methods

Subjects

Volunteers were recruited from the University hall. Firstly, they completed a questionnaire about health status, smoking, eating, drinking and exercise habits. The subjects

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selected were healthy, non smokers, and had not lost any weight in the six months preceding the study; furthermore they rated as pleasant all the foods used. Subsequently an expert dietician interviewed them about their normal energy intake by means of a semiquantitative food frequency questionnaire (Porrini *et al*, 1995c) and estimated their height and weight. Ten women were chosen aged between 20 and 25 y (mean 23.2 ± 2), with a body mass index (BMI) between 18.9 and 23.8 (mean 21.2 ± 2) kg/m^2. They all followed a normal diet according to Italian recommendations (LARN, 1989) and their estimated daily food intake was 7552 ± 756 kJ/24 h (1805 ± 181 kcal/24 h). From the equation of Harris–Benedict (1919) a mean basal metabolic rate of 5740 ± 121 kJ/24 h (1372 ± 29 kcal/24 h) was derived. Before starting the study subjects received a detailed instruction paper and signed a consent form. The protocol was fully explained to the subjects, but none of them knew the true purpose of the study. The protocol was reviewed and approved by the Local Ethics Committee.

Experimental procedure

Each subject was studied throughout a 12 d experiment. The experimental period started exactly 7 d after the beginning of the menstrual cycle so avoiding possible alterations in energy expenditure and intake due to the different phases of the cycle (Piers *et al*, 1995; Webb, 1986; Tangney *et al*, 1991; Barr *et al*, 1995). During the study, with the exception of the test days, all the subjects followed an identical dietary protocol which respected their own habits and energy requirements (Appendix). The protocol was basically a list of instructions whose compliance was checked by means of a 24 h recall once during the experimental period. On the days preceding each test (1st, 3rd, 7th and 11th), the subjects were asked not to do any physical exercise and to have a low protein dinner before 20.00. On the second day subjects reported to the laboratory after having fasted for 12 h and rested quietly for 45 min and then the basal metabolic rate (BMR) was recorded for 30 min. On the test days (4th, 8th and 12th) a light breakfast of 502 kJ (120 kcal), consisting of two slices of low protein bread, 15 g marmalade and tea sweetened with 5 g of sugar, which had been given to each volunteer previously, was consumed at home before 8.00, then, subjects came to the laboratory before 11.00. After 30 min relaxation, the subjects were asked to sit quietly in a reclining chair and after 5 min the machine started to record energy expenditure for 30 min (pre-meal measurement). The volunteers were then shown to a comfortable room where they could eat in a maximum time of 30 min. Each subject received one of the three isoenergetic meals (one rich in protein, one in carbohydrate and one in fat) on each of the three test days, in randomised sequences. At 12.40 the canopy was placed back on the subject's head. Energy expenditure was measured continually until 19.00 with three 20 min breaks at 15.00, 16.20 and 18.00. Mean values were obtained at 20 min intervals. During the measurement subjects were instructed to remain awake and absolutely immobile. They were allowed to watch selected pictures on TV or listen to music. During breaks subjects were free to stand up but they could move just in the laboratory room or if necessary to the bathroom. It was not possible to take into account the energy expended in these periods, but physical activity of subjects during the breaks was almost comparable. At 19.10 a test meal was served and subjects were told to eat as much as they wanted until they felt 'comfortably full'. Intake was assessed by weighing food and drink before and after the consumption. On each test day, the subjects were asked about satiety, fullness and desire to eat immediately before and after the meal and the test meal, and between meals at 1 h intervals; furthermore the palatability of the three meals was rated on a Fixed Point Scale (1—unpleasant; 9—very good).

Foods

The three meals were isoenergetic and consisted of ordinary food items. The energy provided from each meal was mainly due to a specific macronutrient, 68% from protein, 69% from carbohydrate and 70% from fat, respectively for the high protein (HP), high carbohydrate (HC) and high fat (HF) meal. For both the HP and HC meals the energy density was 10.8 kJ/g but for the HF meal it was 17.6 kJ/g. In order to control the dietary manipulation we served the HP and HC meals with 100 ml of water and the HF meal with 200 ml of water, obtaining three meals similar in weight (about 300 g) and energy density (about 7.2 kJ/g). It has already been suggested that water can be an effective diluent to change the energy density of the diet (Pi-Sunyer, 1990). The food used and their nutrient compositions were calculated using a nutrient composition table (I.N.N., 1989) and reported in Table 1.

The test meal consisted of a self selection buffet that allowed *ad libitum* consumption of a variety of 13 different foods and two different drinks. This is described in detail in another paper (Porrini *et al*, 1997).

Respiratory exchange measurements

Indirect calorimetric measurements were taken by using an open-circuit ventilated-hood system (Deltatrac II, Datex Instrumentarium Corp, Helsinki). The system was calibrated at the beginning of each test with a reference gas

Table 1 Nutrient composition of the three meals

	High protein 195 g bresaola 25 g crackers	*High carbohydrate 120 g pasta 80 g tomato sauce 12 g olive oil*	*High fat 90 g mascarpone 41 g crackers*
Fat (g (%en))	12.1 (19.2)	12.7 (20.7)	43.0 (70.1)
Carbohydrate (g (%en))	19.1 (12.6)	101.7 (69.1)	31.3 (21.3)
Protein (g (%en))	96.6 (68.1)	14.0 (10.1)	11.9 (8.6)
Fibre (g)	0.9	3.6	1.3
Energy kJ (Kcal)	2373 (567)	2310 (552)	2310 (552)

mixture (95% O_2 e 5% CO_2). Oxygen consumption (VO_2 L/min) and carbon dioxide production (VCO_2 L/min) were printed out every minute and the mean values for the 30 min pre-meal measurement period and every 20 min during the between meals period were automatically calculated. At each time point energy expenditure (EE) was obtained according to standard abbreviated Weir equation (Weir, 1949): EE (kJ/min) = 16.4 VO_2 (L/min) + 4.6 VCO_2 (L/min). The thermic effect of meals (TEF) was calculated as the post-prandial increase in energy expenditure above the pre-meal values. Both EE and TEF over 7 h period were calculated as the area under the curve using the trapezoidal rule.

Questionnaire on satiety sensations

Information about satiety, fullness and desire to eat, were obtained from a Satiety Rating Questionnaire. Three questions ('How satiated do you feel?', 'How full do you feel?' and 'How great is your desire to eat?') already used in previous investigations (Porrini *et al* 1995a,b; Porrini *et al*, 1997) provided useful information about the satiety condition. The subjects were asked to rate each sensation by drawing a line, parallel to the baseline, across an isosceles triangle (height 15 cm, base 3 cm and area of 22.5 cm^2), oriented horizontally on the paper with the base on the right. The triangle was unbroken and was marked with a word anchor at the apex to indicate the minimum (not at all) of the experienced sensation and at the baseline for the maximum (extremely). The ratings were expressed in cm^2 of area from the apex to the line drawn by the subjects. Variations of all the sensations under study were computed by subtracting basal values from post-prandial data and the areas under the curve were calculated.

Calculations and statistical analyses

Results are expressed as mean ± s.d. Analyses were conducted for a repeated-measures design as all the subjects were given all the meals. Comparison of the data relating to TEF and satiety sensations, was performed by applying a two-way analysis of variance (ANOVA) using type of food (HP, HC and HF meal) and time as factors. A one-way analysis of variance with the type of food as condition was used to analyse TEF and sensations expressed in terms of integrated area under the curve and the food intake data. Following a significant main effect in the ANOVA, individual means were compared using the Least Significant Difference test (LDS) (Gacula & Singh, 1984). Relations between variables were assessed by linear-regression analysis (Pearson Test). Criteria for significance was set at $P < 0.05$. The computer programme STATISTICA for Windows (StatSoft, Inc, Tulsa, OK) was used for the analysis.

Results

Energy expenditure

The mean BMR of the 10 women selected was 5713 ± 335 kJ/24 h (1365 ± 80 kcal/24 h) and did not differ from the mean calculated from the Harris–Benedict equation, 5740 ± 121 kJ/24 h (1372 ± 29 kcal/24 h).

The mean energy expenditure of the volunteers before lunch (11.0–11.30: pre-meal) was 5911 ± 279 kJ/24 h (1413 ± 67 kcal/24 h), the individual CVs for the triplicate measurements were less than 5%. There was a significant difference between the BMR and the pre-meal energy expenditure [$F_{(1,9)} = 6.427$, $P = 0.032$] probably due to the light breakfast consumed by the subjects on the test days.

Table 2 summarises the energy expenditure in the three experimental conditions. Energy expenditure, which was the same through the three experiments in the pre-meal condition, increased significantly more after the ingestion of the HP meal compared to the HC and the HF meals [$F_{(2,18)} = 11.465$, $P < 0.001$]. Consequently TEF for the HP meal resulted significantly higher than the HC and the HF meals [$F_{(2,18)} = 19.502$, $P < 0.001$].

An overall view of TEF following the consumption of the meals is shown in Figure 1. Both the factors considered, type of food $F_{(2,18)} = 20.042$ and time $F_{(15,135)} = 20.348$, influenced energy expenditure significantly $P < 0.001$. Also their interaction was significant $F_{(30,270)} = 6.728$, $P < 0.001$. The energy expenditure rose in the same way immediately after the consumption of all three types of meals, then, the values after the HP meal remained significantly higher and did not return to baseline, whereas the values after the HC and HF meals decrease in the same way and, before dinner, they returned to pre-meal conditions. The mean increases were 0.64 ± 0.30 kJ/min (0.15 ± 0.07 kcal/min), 0.23 ± 0.27 kJ/min (0.05 ± 0.06 kcal/min) and 0.24 ± 0.25 kJ/min (0.06 ± 0.06 kcal/min) on the HP, HC and HF days, respectively.

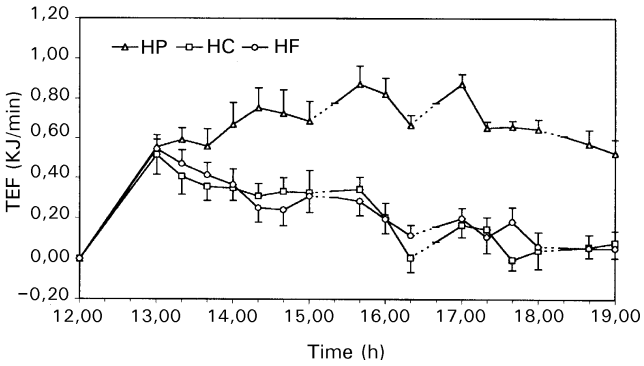

Figure 1 Mean (s.e.m.) thermic effect of food (TEF) after the consumption of the three meals, dotted lines represent the three 20 min breaks.

Table 2 Energy expenditure (mean ± s.d.) after the consumption of the three meals

	High protein	*High carbohydrate*	*High fat*
Pre-meal energy expenditure kJ over 7 h (kcal over 7 h)	1703 ± 111 (407 ± 26)	1724 ± 74 (412 ± 18)	1746 ± 81 (417 ± 19)
Post-meal energy expenditure kJ over 7 h (kcal over 7 h)	1964 ± 109 (469 ± 26)	1816 ± 121 (434 ± 29)	1843 ± 109 (441 ± 26)
TEF kJ over 7 h (kcal over 7 h)	261 ± 59 (62 ± 14)	92 ± 67 (22 ± 16)	97 ± 71 (23 ± 17)
95% confidence intervals (kJ)	218–301	44–140	48–148

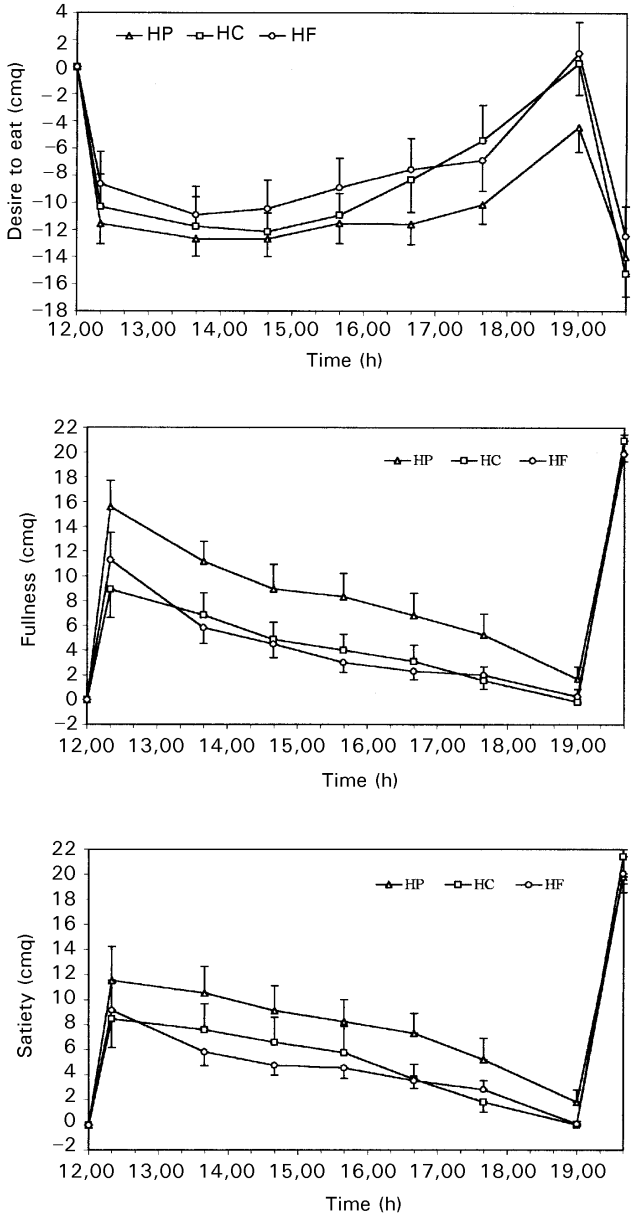

Figure 2 Mean (s.e.m.) sensations after the consumption of the three meals.

Palatability ratings

Mean ratings were 7.7 ± 1.6, 8.0 ± 0.3 and 6.4 ± 1.6 for HP, HC and HF meals respectively. Palatability of HF meal resulted significantly lower than those of the other meals, $F_{(2,18)} = 5.231$, $P = 0.016$.

Desire to eat, fullness and satiety

In Figure 2 the ratings for each of the three questions 'How great is your desire to eat?', 'How full do you feel?' and 'How satiated do you feel?' were plotted as a function of time. As expected, there was a significant change for each sensation with time: $F_{(8,72)} = 39.626$, $F_{(8,72)} = 55.194$ and $F_{(8,72)} = 48.003$, $P < 0.001$, for desire to eat, fullness and satiety ratings respectively.

There was no significant difference in the desire to eat among test days, whereas the interaction between factors (time × type of food) was significant, $F_{(16,144)} = 1.912$, $P = 0.024$. In fact, from 15.40 until the test meal, desire to eat increased less after the HP meal than after the HC and HF meals.

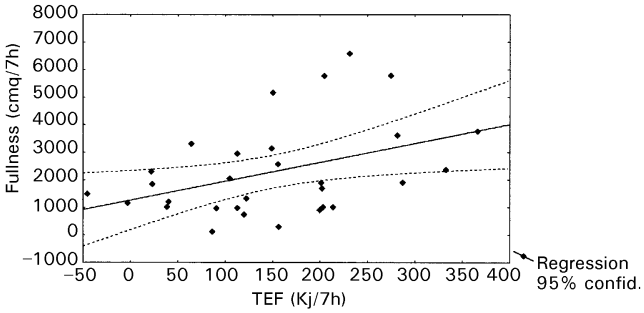

Figure 3 Relationship between AUC fullness and AUC thermic effect of food (TEF), $r = 0.41$, $P = 0.025$.

About the fullness sensation, the type of food was significant $F_{(2,18)} = 8.726$, $P = 0.002$ and also the time × type of food interaction, $F_{(16,144)} = 4.205$, $P < 0.001$. LSD test of overall changes showed that after the HP meal the sensation was the highest at each time-point with the exception at 19.00, when the differences disappeared; furthermore, immediately after the consumption of the HF meal the subjects felt more full than when they had the HC meal. Only for the fullness sensation the analysis of the results expressed as area under the curve showed a significant difference among the three experimental conditions $F_{(2,18)} = 9{,}447$, $P = 0.002$. Fullness was significantly higher after the HP meal ($3439 \pm 1995\,cm^2/7\,h$) compared to HC ($1747 \pm 1376\,cm^2/7\,h$) and HF ($1709 \pm 1117\,cm^2/7\,h$) meals.

For the satiety sensation, the time × type of food interaction was still significant, $F_{(16,144)} = 2.026$, $P = 0.015$, but the type of food did not seem so important as the average values did not differ so much. LSD test showed that a higher satiety feeling was given after the HP meal consumption until 17.40.

Correlation between variables

As reported in Figure 3 simple regression analysis showed a significant relationship between the TEF values and the sensation of fullness calculated as area under the curve ($r = 0.41$, $P = 0.025$).

Food intake

Whichever meal, HP, HC, or HF, was consumed at lunch, the total test meal energy intake did not differ (Table 3). However the energy intake from carbohydrate was significantly affected by the type of food eaten at lunch $F_{(2,18)} = 3.671$, $P = 0.046$, the LSD test showed that the subjects had more test meal energy intake from carbohydrate on HP day than on HF day. In fact on HP day more foods rich in carbohydrate (pasta and apricot tart) were consumed during the test meal while the protein rich foods (ham and salame) were not eaten so much ($P = 0.025$ and $P = 0.046$, respectively). The other types of food were eaten normally.

Discussion

The results of this study show a correlation between TEF and fullness sensations so confirming the hypothesis that there is a link between energy expenditure and eating behaviour.

Table 3 Means ± s.d. of energy intake and percentage contribution of carbohydrate, protein and fat in the test meal

	High protein	*High carbohydrate*	*High fat*
Energy intake kJ (kcal)	4989 ± 370 (1192 ± 88)	4727 ± 253 (1130 ± 60)	4365 ± 250 (1043 ± 60)
Carbohydrate (%)	46 ± 9*	44 ± 6	42 ± 8*
Protein (%)	12 ± 7	15 ± 8	16 ± 9
Fat (%)	42 ± 12	41 ± 8	42 ± 6

* Values significantly different by ANOVA; $P = 0.046$.

Our study, in agreement with many other authors (Welle *et al*, 1981; Dauncey & Bingham, 1983; Nair *et al*, 1983; Kinabo & Durnin, 1990b) confirms that protein is the most thermogenic macronutrient, while no difference was found in the TEF after the carbohydrate or fat rich meal. On the contrary Schwartz *et al* (1985) found that the thermic response after a high fat load was lower than after a high carbohydrate load. In particular, our results show that the higher TEF after eating the HP meal was not due to the initial rise which was similar for all the three meals, but to a constant trend over the time. Presumably, the peak of the TEF curve was due to the meal size (the meals were isoenergetic) whereas the trend was typical for the macronutrient composition and consequently linked to their different rates of absorption and metabolism. Even if the period of measurement was quite long (7 h), the overall quantitative importance of TEF after the HP meal was probably underestimated because the energy expenditure of the volunteers did not return to baseline. However we chose this time interval in order to have subjects in a normal condition with the meals served at 12.00 and 19.00. Moreover the fact that we used three solid proper meals must be stressed. Several studies have investigated the thermic effect of foods but only water solutions of pure nutrients have been used and in the few cases where the macronutrients have been served in proper meals, no comparison of high protein, high carbohydrate and high fat meals in a single research has been made. With the use of liquid meals energy or macronutrient content can be varied without varying food form while this is quite impossible with solid meals. Even if postprandial rise in energy expenditure depends largely on the amount of energy and type of nutrient ingested (Jéquier, 1984; D'Alessio *et al*, 1988), the thermogenic response involves facultative thermogenic mechanisms, which may vary between individuals or in response to environmental stimuli. So it is possible that meals differing in palatability due to different form, taste or texture, result in different degrees of facultative thermogenesis, but the results are still discordant (LeBlanc & Brondel, 1985; Weststrate *et al*, 1990). We can not exclude that the thermic effect of our three meals was influenced by the difference in their forms, however between the two more similar meals, HP and HF, the difference in TEF was high, so confirming the major role of macronutrient composition on thermogenesis.

From the analysis of the sensations related to intake, we can conclude that when isoenergetic loads of protein, carbohydrate and fat were given to normal weight women, protein resulted the most satiating, in agreement with many other authors (Rolls *et al*, 1988; Barkeling *et al*, 1990; Porrini *et al*, 1997; Porrini *et al*, 1995a,b; Stubbs *et al*, 1996). However, under the conditions of the present experiment, the intake of protein was not sufficient to influence energy consumption at the test meal. This seems to be in contrast with other studies (Barkeling *et al*, 1990; Porrini *et al*, 1995a,b). Probably, as reported by Rolls *et al* (1994), the impact of a preload on subsequent food intake diminishes with increasing time from the preload. In the present study there was a 7 h period between preload and test meal and this interval of time could have been too long to highlight differences in food consumption. Like Rolls *et al* (1991) we found no differences between satiating properties of fat and carbohydrate. Johnstone *et al* (1996) using isoenergetic diets, reported that fat and carbohydrate had a more similar effect on hunger and energy intake than protein (which had the strongest effect), even if carbohydrate tended to have a more rapid suppressive effect on hunger, while fat had a more delayed action. On the contrary other authors found that fat was less satiating than carbohydrate due to its high energy density and/or to its great effect on palatability (Blundell *et al*, 1993; Lawton *et al*, 1993; Green & Blundell, 1996). In our study the HF meal was made with a high fat cheese (mascarpone) and crackers, instead of a high fat cake in order to have a savoury main course similar to the others and not a dessert. In this way we obtained a HF meal slightly less preferred than the other two meals (HP and HC) avoiding the effect of palatability on satiety.

Many different papers report a high satiating capacity for protein. The mechanisms involved in nutrient appetite-control are not clear, however protein could induce both post-ingestive (for example CCK release) and post-absorptive (for example fluctuation of plasma amino acids concentrations) signals. On the other hand many studies (Stubbs *et al*, 1995; Flatt, 1995) suggested that the high satiating capacity of protein is partially linked to the ability of the body to increase protein oxidation in response to an increase of protein intake. In a recent study, Stubbs *et al* (1996) compared the effect of isoenergetic high-protein, high-fat or high-carbohydrate breakfasts on energy balance and subjective appetite over a 24 h period. They found that protein exerted the strongest effect on satiety while the level of energy balance obtained at the end of the 24 h period was very similar for the three dietary treatments. Protein balance was significantly increased in the high-protein treatment, while carbohydrate and fat balance were not significantly different. The authors concluded that the effect of protein on satiety could be 'partly related to the increased rate of obligatory oxidative disposal of the positive protein balance that attends the formation and excretion of urea'. In the present work energy expenditure is well correlated with subjective sensations of fullness, consequently it seems possible to hypothesise that the thermic effect of protein is partly responsible for the satiating properties of this nutrient and that it plays a role immediately after ingestion, even if its contribution becomes more important about 1 h later. To explain the relationship between TEF and satiety, it is important to

consider that autonomic functions, such as eating behaviour and thermoregulation, are primarily controlled by the hypothalamus, consequently the mechanism involved in raising metabolism after food intake could be involved also in triggering satiety (Rothwell, 1992). The energostatic theory proposed by Booth (1972) states that the energy produced by the metabolism of absorbed nutrients is monitored to regulate food intake: specific temperature receptors in the brain would activate and terminate ingestive behaviour. On the basis of this theory Westerterp-Plantenga *et al* (1990), studying the relationship between eating behaviour (measured as cumulative food intake curves), postprandial thermogenesis and skin temperature of different groups of women (normal weight, obese, restrained and unrestrained) concluded that the thermic effect of food, and to a lesser extent body temperature, decelerate cumulative food intake curves, controlling eating behaviour.

Conclusions

Our results could indicate that the thermic effect of foods contributes to their satiating power but further studies are needed to better understand the relationship between the composition of the diet (high in one nutrient or balanced) and satiety. If we could improve our knowledge in this specific field we would be able to give better information on how to avoid overfeeding.

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Appendix

Dietary protocol followed by the subjects during the 12-d experiment.

Breakfast	Semi-skim milk	200 ml
	Coffee	
	Sugar	5 g
	Biscuits	50 g
	Water	
Snack	Crackers	25 g
	or Yoghurt with fruit	125 g
Lunch	Bread	70 g
	Ham	70 g
	Cheese	100 g
	Vegetables, raw or cooked	150 g
	with Olive oil	15 g
	Apple	150 g
	Coffee	
	Water	
Dinner	Spaghetti	70 g (raw)
	with Tomato-puree	17 g
	or Olive oil	15 g
	Vegetables, grilled	100 g
	Bread	50 g
	Water	

Note: for each item one or more substitutions were provided on the basis of the nutritional characteristics: i.e. Biscuits 50 g or Cake 50 g; Ham 70 g or Beef steak 100 g.