SERVING A HIGH MEAT PROTEIN LUNCH REDUCES SUBSEQUENT ENERGY INTAKE AT DINNER: A RANDOMISED TRIAL CONDUCTED IN A REAL-LIFE SETTING

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Abstract – Evidence regarding the satiating effects of protein is well documented in controlled clinical trials. In a broader perspective, it is important to consider whether a dietary pattern with high protein can affect energy intake in real life. The aim of the study was to investigate how high protein meals containing pork affect appetite and energy intake when given to adolescents in daily surroundings. The study included 134 students aged 15-16 at a boarding school. On separate occasions, the subjects were randomly given a high meat protein lunch or a normal lunch. Appetite was measured by visual analogue scales (VAS), energy intake was assessed at an *ad libitum* dinner and snack intake was recorded. A high meat protein lunch (35E% protein) reduced dinner energy intake (-250 kJ) compared with a normal lunch (15E% protein) (p=0.0182). Interestingly, there was a trend towards a reduced daily energy intake following the high meat protein lunch (p=0.0561). Serving a high meat protein lunch did not affect the habitual snack intake (p=0.3357). VAS ratings for hunger and fullness did not differ between the meal patterns. In conclusion, high meat protein meals and snacks could be served in a school setting to reduce energy intake.

Key Words – food intake, meat protein, satiety

I. INTRODUCTION

Obesity and related lifestyle diseases are a major public health concern. To address this problem, it is necessary to identify effective tools to prevent weight gain in the population.

It is well-established that proteins are more satiating per calorie than carbohydrates or fat. Numerous studies have shown that consuming protein-rich meals may lead to a reduced energy intake compared with carbohydrates or fat, thus facilitating a negative energy balance [1,2,3]. These studies are typically conducted under controlled conditions at a university, often including only a small number of study participants. However, the evidence suggests that an increase in protein intake at the expense of the other macronutrients may promote satiety and reduce energy consumption. Furthermore, long-term studies have shown that a diet replacing modest amounts of dietary carbohydrate with proteins can improve weight loss and fat-free mass [4] and maintain weight loss [5].

The aim of the present study was to translate the scientific evidence regarding the satiating effect of proteins into a real-life setting and assess how a high meat protein lunch affects appetite and energy intake.

II. MATERIALS AND METHODS

Study design

The study had a randomised within-subject design and was performed at a Danish boarding school. The study location was a unique setting in that the study participants lived their daily lives and consumed their meals at the school and were therefore able to behave as they would ordinarily do. The two isoenergetic intervention meals were: a high meat protein lunch (≈35% of energy from protein) and a normal lunch following the Nordic Nutrition Recommendations with regard to protein (≈15% as protein).

On two consecutive days, the students were randomly given the two lunch meals. This was repeated over the following weeks.

An *ad libitum* buffet-style evening meal was served for dinner to measure the subsequent food intake. The participants were instructed to eat until comfortably satiated. The *ad libitum* meal was standardised and consisted of Danish rye bread, assorted sliced cold meats, butter, vegetables and

fruit. The amount of food consumed was recorded, and the energy intake was calculated.
A food frequency questionnaire (FFQ) was used to assess the intake of habitual snacks and foods consumed between meals during each test day. The snack intake was self-reported by the participants. The FFQ was developed based on a small pilot study which described the most typical snacks and foods consumed by teenagers during the day.
On each test day, the participants had their usual breakfast at school under the assumption that the food and drink intake was habitual.

Subjective appetite ratings of hunger, fullness and liking were measured on a 150 mm Visual Analogue Scale (VAS) at five times per test day: 12:00, 12:30, 3:30, 6:00 and 6:30 p.m. As an example, the question "How hungry do you feel right now?" was rated along the scale anchored with "Not at all" on the left and "Extremely hungry" on the right. The participants then made a mark across the line indicating their feeling at each of the above times.

Subjects
The study participants were students aged 15-16, and they all participated on a voluntary basis. Participants who did not eat meat or pork were not included in the study and the data analysis.

Lunch meals
The lunch meals were hot meals based on dishes popular among the study participants. Examples of the meals served were pork loin with gravy, potatoes and salad; smoked pork loin with scalloped potatoes and salad. On each test day, the two intervention lunches were made from the same dish and served in a fixed portion size according to the designed nutritional composition of the two intervention meals. The lunch meals varied according to their protein and carbohydrate composition and were designed to have the nutritional composition shown in Table 1.

Statistical methods
The energy intake at lunch, as a snack and during the whole day was analysed by a mixed model with lunch meal as a fixed effect and student and student*lunch meal as a random effect.
Appetite data was analysed by a mixed model with student and lunch meal*student as a random effect, type of lunch meal as a fixed effect and the actual energy intake as a co-variant (SAS vers. 9.2, SAS Institute, Cary, USA).

Table 1. Energy and macronutrient composition of lunch meals (n = 4) based on chemical analyses

Nutrients	High meat protein lunch	Normal lunch
Energy (kJ/100g)	572	531
Protein (E%)	34	18
Carbohydrate (E%)	37	55
Fat (E%)	29	26

III. RESULTS AND DISCUSSION

Lunch meals
In general, the participants did not finish their lunch meals completely, although they were encouraged to do so. Food that was not consumed was weighed, and the actual nutrient intake was calculated (Table 2). A significantly higher energy and fat intake was found for the participants consuming the normal lunch ($p<0.0001$ for both fat and energy intake). Nevertheless, the energy distribution over the macronutrients of the ingested lunch corresponded reasonably with the lunch meals presented in Table 1.

Table 2. Actual nutrient intake and composition of the consumed lunch meals. The results are shown as mean values of the four lunch meals.

	High meat protein Lunch	Normal Lunch
Energy	2235 kJ	2480 kJ
Protein	47 g 36 E%	25 g 17 E%
Carbohydrate	43 g 33 E%	74 g 51 E%
Fat (g)	19 g 31 E%	21 g 32 E%

Energy intake (ad libitum meal, snack and daily)
The lunch meal affected the amount of food consumed at dinner since there was a significant effect of lunch type on *ad libitum* dinner energy intake ($p=0.0182$) (Figure 1). The high meat protein lunch resulted in a lower energy intake than the normal lunch (-250 kJ). The lower energy

intake at the high meat protein lunch was therefore not compensated for at the *ad libitum* dinner.

The reduction in dinner energy intake is possibly due to the higher protein intake (almost twice the amount) at lunch. Proteins are assumed to exert their satiating effect through the release of satiety-related peptides from the stomach and different parts of the intestine. Also, the metabolism of amino acids and their ability to serve as precursors for specific neurotransmitters involved in appetite regulation have been proposed. The results of the present study suggest that proteins are acting through an effect in the late or post-absorptive satiety rather than the immediate or early phase, as the suppression of food intake occurred 5-6 hours after the high meat protein lunch was provided.

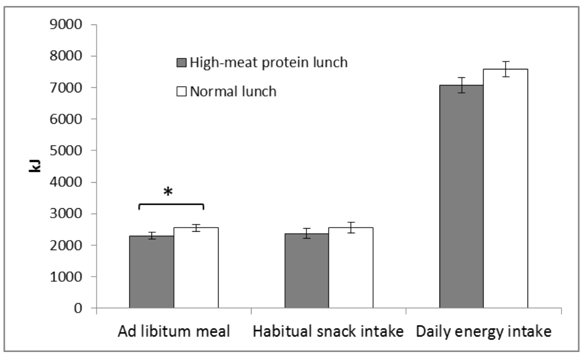

Figure 1. *Ad libitum* energy intake; total snack intake during the day and total daily energy intake for the high meat protein lunch and the normal lunch. A significant difference ($p<0.05$) between the lunch meals is indicated by a *.

The self-reported snack and food intake between meals consisted primarily of fruit, biscuits, popcorn and sweets (data not shown). No difference in snack energy intake was found, irrespective of whether a high meat protein or a normal lunch was consumed ($p=0.3357$) (Figure 1). These results are not in line with the results regarding the observed reduction in dinner energy intake, which suggests that other factors could control energy intake from snacks between meals. Cultural background, tradition and social circumstances can strongly influence appetite and food intake. The study was performed at a Danish boarding school where the study participants live their daily lives and where social life and gatherings are areas of priority. Between classes and the main meals, the students went to the local kiosk or bakery, gathered around the television or relaxed – all activities involving food. Also, the study population was teenagers aged 15-16, which could be an age at which food or food restriction can be used to cope with emotional imbalance and mood swings. In these cases, physiological responses may not be the determining factor for which type of food and how much food is consumed.

The daily energy intake was estimated as the sum of energy intake from the lunch meal plus snacks consumed during the day plus the *ad libitum* evening meal. The energy intake from the breakfast meal was not included in the calculations. A tendency towards a significantly reduced daily energy intake was found when the high meat protein lunch was consumed ($p=0.0561$) (Figure 1). The reduction in energy intake at the *ad libitum* dinner (≈250 kJ) and the potential reduction in daily energy intake play a small but important role in maintaining energy balance.

There is considerable evidence that protein decreases subsequent energy intake in the short term and has an impact on body weight in the longer term, as mentioned in the introduction. The Nordic Nutrition Recommendations are currently being reviewed and revised in areas where new scientific knowledge has emerged, such as protein. New evidence regarding high protein diets, accompanied by low glycemic index foods, challenges the current official Nordic recommendations and concludes that these are not sufficient to prevent obesity [5].

Appetite

The results of the subjective appetite measurements did not correspond with the findings on energy intake after the high meat protein lunch, since the hunger and fullness ratings were not significantly different between the two lunch meals (Figures 2 and 3). One exception was after the lunch meal, as the normal lunch increased fullness significantly ($p=0.0460$). The immediate increase in fullness after lunch could be explained by the higher energy, fat and carbohydrate intake at the normal lunch (Table 2).

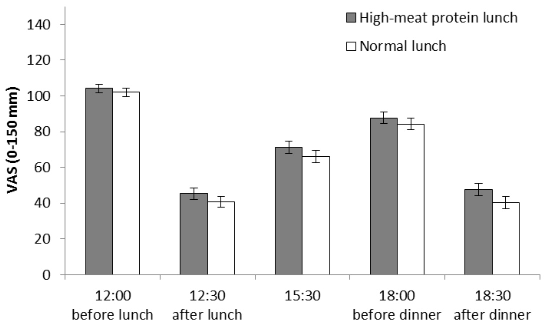

Figure 2. Hunger (least square means ± standard error) of the high meat protein lunch and the normal lunch. A significant difference ($p<0.05$) between the lunch meals is indicated by a *.

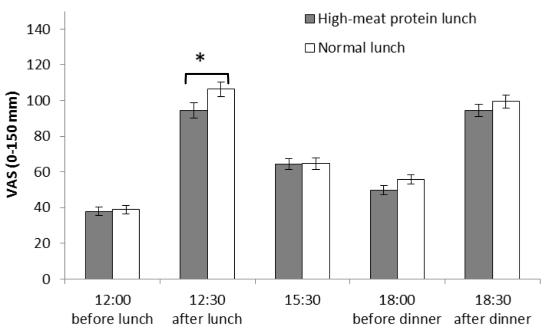

Figure 3. Fullness (least square means ± standard error) of the high meat protein lunch and the normal lunch. A significant difference ($p<0.05$) between the lunch meals is indicated by a *.

The lunch meals were generally liked by the participants, but an effect of test day was observed on the liking ratings ($p=0.0085$). Nevertheless, the acceptance of the lunch meals did not differ between the two lunch meals ($p=0.2581$) and nor did the interaction between lunch and day ($p=0.2090$).

Subjective appetite measurements were only made before and after the main meals and one time during the afternoon (two hours after lunch), which may not be adequate to observe the complete appetite pattern during the day. Other studies measure appetite more frequently (every half hour or hour), and the low frequency of the appetite measurements is therefore one drawback of the present study.

IV. CONCLUSION

In conclusion, consumption of a high meat protein lunch, with 35% of energy from protein, results in a reduced dinner energy intake of ≈250 kJ among a large group of students in a real-life setting. This decrease in energy intake could have an overall effect on the daily energy balance, as a tendency towards a reduced daily energy intake was also observed. These effects appear to be attributable to the meat protein content of the lunch meal. No significant effects could be demonstrated on subjective appetite ratings.

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