Fat and non-absorbable fat and the regulation of food intake

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STELLINGEN

1. Het gebruik van een niet-absorbeerbare vetvervanger in voedingsmiddelen in plaats van vet resulteert in een vermindering van de dagelijkse vet- en energie-inneming, zonder dat daarbij de hongergevoelens toenemen. (dit proefschrift)

2. De energie-inneming van de mens wordt niet nauwkeurig gereguleerd voor perioden korter dan enkele weken. (dit proefschrift)

3. Het gebruik van vetvervangers kan helpen bij het voorkomen van toename van het lichaamsgewicht. (dit proefschrift)

4. Het is niet mogelijk om de energie-inneming van een maaltijd nauwkeurig te voorspellen aan de hand van de mate van honger en verzadiging voorafgaand aan die maaltijd. (Mattes, Appetite, 1990;15:103-113; dit proefschrift)

5. Het gebruik van vetvervangers heeft vooral een gunstig effect op de gezondheid wanneer het verzadigd vet van produkten wordt vervangen.

6. Aangezien mensen geen macronutriëntspecifieke verzadiging vertonen zal het gebruik van vetvervangers leiden tot een voeding die beter aansluit bij de Richtlijnen Goede Voeding dan het gebruik van suikervervangers.

7. Een goede manier om mensen gezonder te laten eten is door het aanbod van voedingsmiddelen gemiddeld gezonder te maken.

8. Het rapporteren van absolute waarden van eetlustgevoelens verdient de voorkeur boven waarden waarbij de initiële waarde als referentiepunt wordt gebruikt, omdat er geen enkele aanwijzing is dat verschillen in eetlust voor de consumptie van een maaltijd invloed hebben op eetlustgevoelens na de maaltijd.

9. Door de krappere arbeidsmarkt als gevolg van de toenemende bezuinigingen binnen de onderzoekswereld zouden AIO's een bredere opleiding moeten krijgen dan enkel die tot onderzoeker.

10. De sterke overschatting van het percentage studenten dat de goedkopere weekend- in plaats van de week-OV-jaarkaart kiest, geeft aan dat het Ministerie van Onderwijs de gevoeligheid voor economische prikkels van studenten heeft onderschat.

11. Ondanks het toenemende aantal televisiezenders waaruit gekozen kan worden, neemt de kijkvreugde niet toe.

12. Promoveren is als het rijden van de Tour de France.

Stellingen behorend bij het proefschrift
"Fat and non-absorbable fat and the regulation of food intake"
van Toine Hulshof.

Wageningen, 16 november 1994.

Aan mijn ouders

CONTENTS

ABSTRACT

Fat and Non-Absorbable Fat and the Regulation of Food Intake.

Thesis by Toine Hulshof, Department of Human Nutrition, Wageningen Agricultural University, The Netherlands, November 16, 1994.

The effects of consumption of meals with differences in energy-, fat-, protein-, carbohydrate-content, and physical state on subsequent dietary intake and feelings of appetite, were investigated in eight different studies. The main objective was to study whether or not humans compensate for the covert and overt energy differences, obtained by replacement of fat by a fat-replacer, in both the short (1 day) and long term (12 days). As fat-replacer the non-absorbable sucrose polyester (SPE) was used. A second objective was to investigate some methodological issues of research on food intake regulation.

In normal weight men and women little compensation was found for the energy differences after the different meals. In all eight studies, mean energy compensation was less than 50% for both men and women, with an average for all studies of 14%, based upon a meta-analysis. No substantial differences in the level of energy compensation were found between men and women, or between the short and long term studies.

Independent of the level of energy compensation, no macronutrient specific compensation was found. This means that the macronutrient composition of the subsequent dietary intake was similar after each meal manipulation. As a result the consumption of SPE lead to a decrease in daily fat intake.

When artificial products (i.e unidentifiable formula products) were given to the subjects, lower energy levels resulted in higher hunger ratings. When the energy manipulations were carried out with normal food products, small or no differences in feelings of appetite were found.

The three macronutrients (fat, carbohydrate, protein) were equally satiating, and solid products were more satiating than liquid products.

It is concluded that normal weight men and women do not, or poorly recognize covert energy differences between meals, and poorly adjust their food intake of subsequent meals after both covert and overt energy manipulations. Therefore the replacement of fat by a non-absorbable fat-replacer such as SPE can help to reduce both the daily energy and fat intake in normal weight humans.

CHAPTER 1

GENERAL INTRODUCTION

Fat-replacers are ingredients that can replace, partly or completely, the dietary fat of foods, preferably without changing the sensory and physical properties of the food. The use of fat-replacers result in a decrease of both the fat- and energy content of a food. These low-fat/energy products might help in reducing the dietary fat and energy intake. A reduction of fat intake is in line with the current health recommendations in the Western Countries[1-3], and a reduction of energy intake could prevent people from becoming overweight, and thus help in body weight regulation.

One of the most interesting questions with respect to the use of low fat/energy products is their effectiveness: Does the decrease in energy intake, by the use of low fat/energy products, increase feelings of hunger, and does their use lead to a decreased overall consumption of energy or fat. In the studies of the present thesis, the non-absorbable fat-replacer sucrose polyester (SPE) was used as a tool to reduce the fat and energy content of foods and meals.

The non-toxic sucrose polyester is a fat-replacer that has a good resemblance to edible oils and fats. Currently SPE has been used in nutritional and clinical trials, but it is not yet approved for use in consumer food products. At the moment its long term safety is under discussion of regulatory authorities in the U.S.A.. SPEs have a similar appearance, and the same physical and sensory properties as normal dietary fat, but are not digested and absorbed in the human body.[4] Sucrose polyesters are synthesized by esterification of sucrose with medium- and long-chain fatty acids (mostly C12 to C20) from oil sources that may be saturated or unsaturated.[5,6] The nature of the ester can be altered by changing the constituent fatty acids.[7,8]

SPE is not absorbed in the gut, and it leaves the body in the same chemical state as it came in. Depending on the nature of the fat or oil used to prepare SPE, stools may become softer and greasier by the use of SPE. In cases SPE is liquid at body temperature, anal oil leakage can occur.

Because SPE is not absorbed and remains in the gut, it forms an oil-phase in which fat soluble nutrients can dissolve. Depending on the hydrophobicity, these fat-soluble substances may leave the body, partially or completely, with the SPE. A positive aspect of this quality of SPE is that serum cholesterol levels decrease after SPE consumption.[4,9-13] However, consumption of SPE can also decrease the absorption of fat-soluble vitamins, medicines and oral contraceptives. After SPE consumption, decreases have been found in serum levels of vitamin A[4,9,10] and vitamin E[4,9,10,12], and less or no effects were found in vitamin K[9,12,14], vitamin D[9,12,15] or oral contraceptives[16]. Besides this physiological effect, the intake of fat-soluble vitamins can also be decreased because of the replacement of dietary fat, containing the fat-soluble vitamins, by the vitamin-free containing SPE.

Previous studies on the effectiveness of SPE show different results. In the only long-term study (20 days) with SPE of Glueck et al.[9] no energy and fat compensation was found in 10 obese subjects. In the short-term studies (1 day) of Rolls et al.[17], Blundell et al.[18], and Birch et al.[19] complete energy compensation was reported. However, in all four studies the compensation found was not fat specific. The effectiveness with respect to fat intake was good, implying that the percentage energy derived from fat was reduced. The effectiveness with respect a reduction in dietary energy intake remains unclear.

Appetite, satiety and energy compensation

For a clear understanding of the thesis, some phenomena or processes with respect to research on the control of appetite feelings and the regulation of food intake need to be explained first. The control of appetite involves two different processes, **satiation** and **satiety**. **Satiation** is the process that terminates the eating within a meal. **Satiety** is the state that occurs after the meal, and inhibits further eating. The term **hunger** is directly correlated with satiety, although it works in the opposite direction. **Satiation** determines how much people eat during a meal, and **satiety** determines how long people abstain from eating after a meal.[18] The effects of different meals on **satiation** can be measured by supplying subjects with an abundance of a food, and measuring how much of that food is eaten ad libitum. The effects of the consumption of a fixed meal on subsequent **satiety** can be measured in two different ways. The first is to ask the subjects to rate their subjective feelings of hunger and satiety. The second method is to measure the subsequent ad libitum food intake. The present thesis investigates effects of different food manipulations on **satiety**, and not on satiation. The **satiating effect (satiating power or satiating efficiency)** of a food item is defined as the extent to which a certain food item is capable of suppressing feelings of appetite or subsequent energy intake.

The terms **preload** and **testmeal** can best be explained by using the example of the **preload-testmeal** design. In this design a fixed amount of manipulated food is given to the subjects (**the preload**), which has to be consumed completely by the subjects, and which is followed by a **testmeal** from which the subjects can eat as little or as much as they want. The consumption in the testmeal gives an indication of the satiating power of the different preloads.

An important measure of the effectiveness of an energy (fat) replacement is the extent of energy/fat compensation after a low-energy (fat) meal compared with a non-manipulated meal. The measure **energy compensation** is used to investigate how much of the energy differences between the manipulated meals (preloads), is compensated for by changes in energy intake after the preload consumption. In the present thesis **energy compensation** is calculated as the negative value of the slope of the line between the energy levels of the preloads and the ad libitum energy intake after these preloads, as was described by Kissileff[20,21].

Figure 1 shows a hypothetical example of three persons who all have a normal daily intake of 10.0 MJ, and who are receiving three different preloads. The first preload is a breakfast with normal food products that contains 4.0 MJ. In the second breakfast 26 gram fat is replaced by 26 gram SPE resulting in a breakfast of 3.0 MJ, and in the third breakfast 52 g fat is replaced by 52 g SPE resulting in a breakfast of 2.0 MJ. The three persons react differently to the changes in energy levels of the preloads. Subject A clearly recognizes the decrease in energy level in the breakfasts with SPE, and compensates in a way that the total energy intake at the end of the day is still 10 MJ (complete energy compensation). Subject B recognizes some differences between the preloads although not very precise and compensates only for half of the energy differences due to the substitution of fat by SPE (50% energy compensation). The total energy intake at the end of the day with the low-energy breakfast is therefore reduced to 9 MJ. Subject C. does not recognize any difference between the three preloads, and consumes the remainder of the day the similar amount as after the 4.0 MJ breakfast. Subject C. will decrease the energy intake on that day by an amount equal to the manipulation.

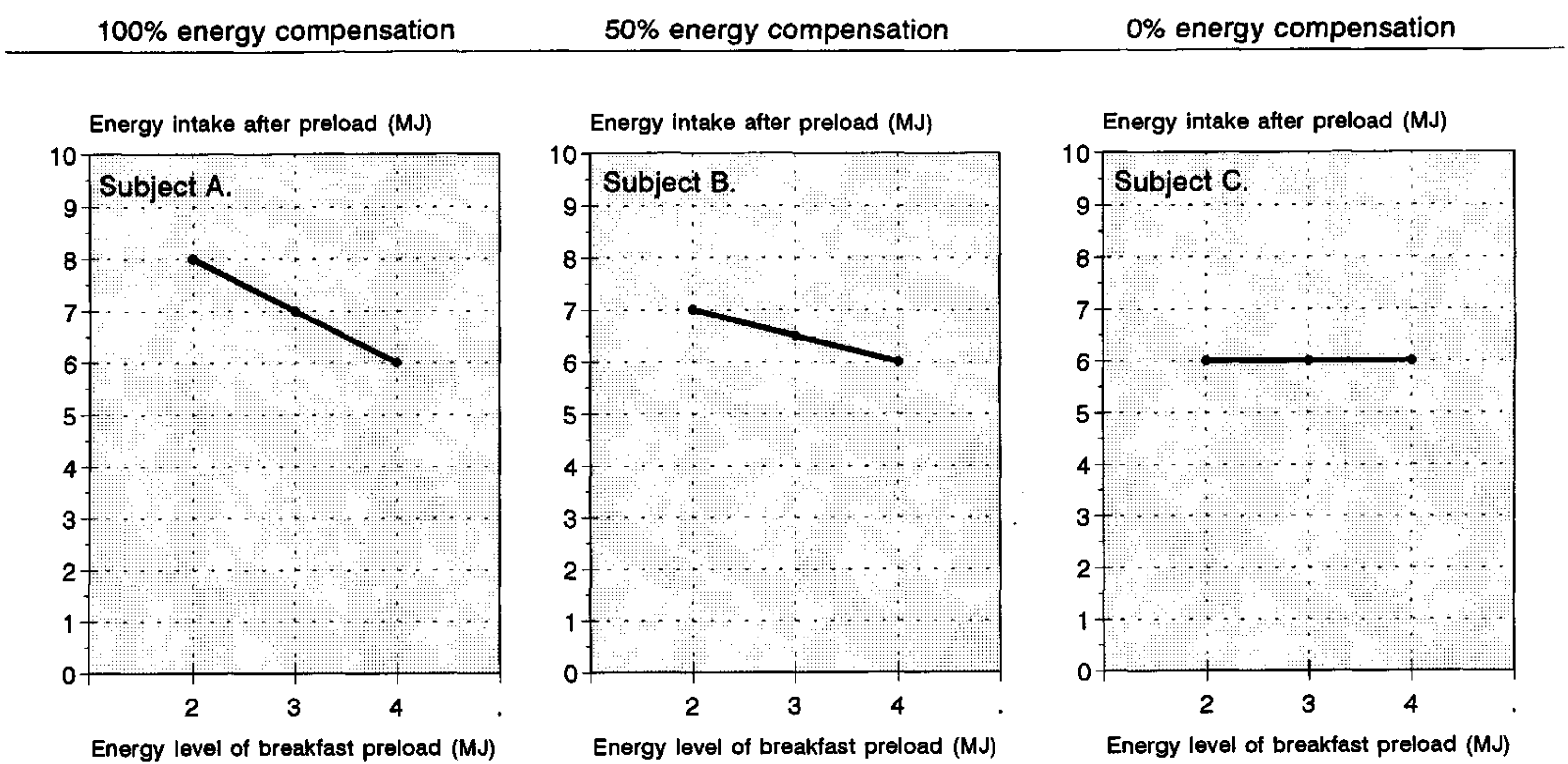
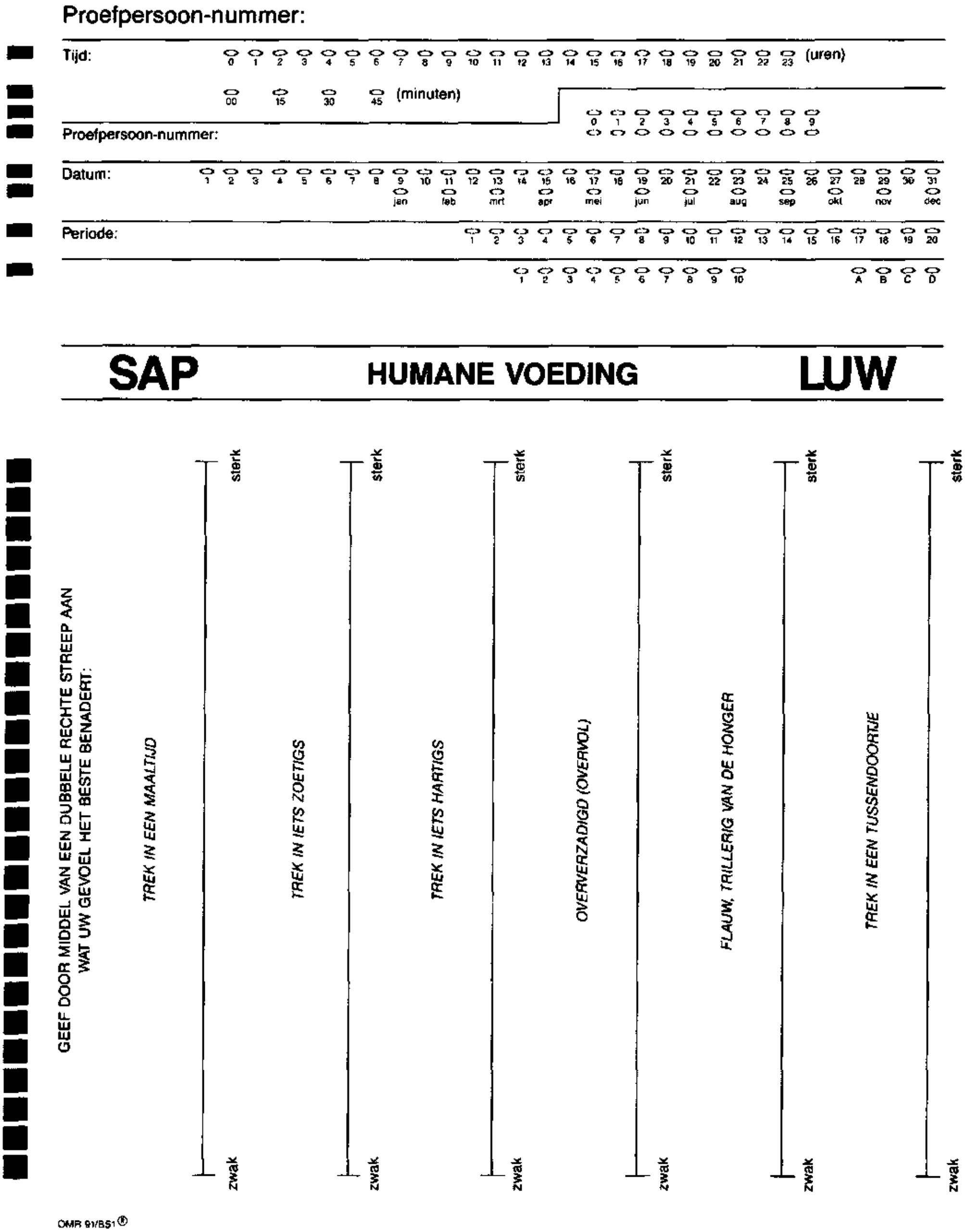


Figure 1. Examples of the calculation of energy compensation for three hypothetical subjects (A, B, C) with a mean daily intake of 10 MJ, and who receive three different breakfast manipulations. The first breakfast was with normal food products and contained 4.0 MJ. In the second breakfast 26 g of dietary fat was replaced by SPE resulting in an energy content of 3.0 MJ, and in the third 52 g fat was replaced by 52 g SPE resulting in a breakfast of 2.0 MJ. The subjects compensate differently for the given energy manipulations (100, 50, and 0% energy compensation).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1 2 3 4 5 6 7 8 9 10 A B C D

SAP HUMANE VOEDING LUW

GEEF DOOR MIDDEL VAN EEN DUBBELE RECHTE STREEP AAN WAT UW GEVOEL HET BESTE BENADERT:

TREK IN EEN MAALTIJD (zwak – sterk)

TREK IN IETS ZOETIGS (zwak – sterk)

TREK IN IETS HARTIGS (zwak – sterk)

OVERVERZADIGD (OVERVOL) (zwak – sterk)

FLAUW, TRILLERIG VAN DE HONGER (zwak – sterk)

TREK IN EEN TUSSENDOORTJE (zwak – sterk)

OMR 91/851®

Figure 2. A visual analogue rating scale (VARS) with 6 items on appetite feelings.

The development of a measurement device for appetite feelings

When appetite for a certain food item is high, then this does not necessarily mean that appetite for another food item is also high. Appetite is not a one-dimensional construct, but consists of different specific appetites. In this thesis the items on feelings of appetite were derived from the so-called Dutch Appetite Rating Scale (DARS) developed at Unilever Research Laboratorium Vlaardingen. The DARS consisted of 29 questions about feelings concerning with food intake. The DARS is divided in items referring to "appetite for a meal", "appetite for a snack", "feeble, weak with hunger", and "satiety/fullness". Answering a DARS form takes about 5 minutes. As it was intended to measure feelings of appetite frequently (up to 20 times per day), it was decided to develop a measure that could be dealt with much faster. This was the so-called visual analogue rating scale (VARS) and could be filled in within a minute. The appetite items on this 150 mm VARS were derived from DARS. "Appetite for a snack" was divided in: "appetite for something sweet" and "appetite for something savoury". Thus, the VARS consisted of five items.

In the study presented in Chapter 2 additional analyses were performed on the reproducibility of the 5 appetite items of the VARS and the 29 questions of the DARS. The study revealed that satiety/fullness had to be changed to oversatiety/overfullness, and that appetite for any snack had to be included, as the other two snack items could not cover all the appetite for snacking.[22] As a result a visual analogue rating scale with 6 appetite items was made (see figure 2). This study also showed that the appetite ratings were reproducible and valid.[22]

Outline of the thesis

In all studies described in the present thesis the effects of energy differences in preloads on subsequent food intake and appetite feelings were investigated. The first four studies also concerned some methodological issues.

Table 1 shows the differences in methodology between the studies described in this thesis. In Chapter 2 the satiating effects of carbohydrates, protein and fat were investigated, at three different energy levels. No differences were found between the three energy levels (0.42, 1.05, and 1.67 MJ) of the study from Chapter 2. It was decided to increase the energy differences between the preloads in the next experiment to 2.9 MJ, as it was expected that at a certain level of energy differences between the preloads, effects on food intake or appetite feelings should be found. The preloads used in Chapter 2 were liquid preloads. Chapter 3 describes the effects of different physical states (liquid and solid), with three different energy levels (by fat manipulation), on subsequent food intake and feelings of appetite.

The studies in Chapter 2 and 3 were carried out with artificial preloads (unidentifiable formula foods). In chapter 4 the effects of real foods (croissants) at three different energy levels was studied. This was the first study of this thesis where sucrose polyester (SPE) was used as a fat-replacer. In the study described in Chapter 4 the effects of croissants on subsequent ad libitum food intake and feelings of appetite as a function of the time of preload consumption were studied. The subjects consumed each of the three preloads at either 0800, 1230 or 1500 hrs. In Chapter 5 the effects of high-fat and low-fat/high-SPE croissants were investigated. This was done with three different deprivation periods following the preload intake. In Chapter 6 a replication study was carried out on the effects of different fat and SPE levels in warm luncheon meals on subsequent energy intake. This study included a test meal in which food intake was observed. All studies described in Chapter 2 to 6 were short-term (one day) studies. Two long-term studies on the effect of SPE are written down in Chapter 7. In this Chapter two replication studies on the effects of 12 days SPE or fat consumption in a three course dinner meal on energy intake, appetite feelings and body weight were investigated. In the first of the replication studies the subject were unaware of the energy manipulation, whereas in the second the subjects were told whether they received a high or a low energy dinner.

In the general discussion an overview of the results of the presented studies is given and discussed.

Table 1. The characteristics of the eight different studies presented in this thesis

Study (chapter)	Preload manipulations	N	Nr of preloads (#xdays)	Kind of Preloads	Physical state	Time of PL consumption	Energy levels PL (MJ)	Energy manipulation	Deprivat. time (hrs:min)	Aware of PL manip.	Dependent variables
1 (2)	Energy level Macronutrients	29	10 x 1 day	Artificial (550 ml/PL)	liquid	breakfast	0.0 / 0.4 1.1 / 1.7	fat/ protein/ carbohydrate	3:30	No	ad lib EI day 1 appetite feelings
2 (3)	Energy level Physical state	33	9 x 1 day	Artificial (550 ml/PL)	liquid/ solid	breakfast	0.4 / 1.7 3.4	fat	3:30	No	ad lib EI day 1+2 appetite feelings
3 (4)	Energy level Consumption time	33	9 x 1 day	Croissants (170 g/PL)	solid	breakfast/ lunch/dinner	1.7 / 2.5 3.4	fat/ SPE	3:15	No	ad lib EI day 1+2 appetite feelings
4 (5)	Energy level Deprivation time	34	6 x 1 day	Croissants (170 g/PL)	solid	lunch	1.7 / 3.4	fat/ SPE	0:15/ 2:15/4:45	No	ad lib EI day 1+2 appetite feelings
5 (6)	Energy level	39	6 x 1 day	Rice meal (500 g/PL)	solid	lunch	1.9 / 2.8 3.8	fat/ SPE	1:45	No	EI test-meal day 1 ad lib EI day 1+2 appetite feelings
6 (6)	Energy level	35	6 x 1 day	Macaroni meal (450 g/PL)	solid	lunch	1.7 / 2.6 3.6	fat/ SPE	1:45	No	EI test-meal day 1 ad lib EI day 1+2 appetite feelings
7 (7)	Energy level	48	2 x 12 days	3 course meals (750 g/PL)	solid+ liquid	dinner	3.1 / 5.0	fat/ SPE	0:00	No	ad lib EI day 1-12 body weight appetite feelings
8 (7)	Energy level	47	2 x 12 days	3 course meals (750 g/PL)	solid+ liquid	dinner	3.1 / 5.0	fat/ SPE	0:00	Yes	ad lib EI day 1-12 body weight appetite feelings

PL=preload; Deprivat.=Deprivation; Manip.=Manipulation; SPE=sucrose polyester; Ad lib EI = ad libitum energy intake; day 1+2 = study day + day after study day

The main questions investigated in this thesis:

What are the effects of:

1) different energy levels of foods
   - in the short-term (1 day) (Chapters 2, 3, 4, 5, 6),
   - in the long-term (12 days) (Chapter 7),
2) different macronutrients (Chapter 2),
3) different physical states of foods (Chapter 3),
4) consumption of foods at different times of the day (Chapter 4),
5) different deprivation periods after preload consumption (Chapter 5).

On:

1) subsequent dietary intake (in all studies),
2) subsequent appetite feelings (in all studies),
3) body weight (in the long-term studies).

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CHAPTER 2

SHORT-TERM EFFECTS OF DIFFERENT AMOUNTS OF PROTEIN, FATS, AND CARBOHYDRATES ON SATIETY.

Cees de Graaf, Toine Hulshof, Jan A. Weststrate, Pauline Jas

ABSTRACT

This study investigated the satiating effects of proteins, fats and carbohydrates (CHOs). Twenty-nine female, normal-weight subjects each received 10 liquid breakfasts, which varied in energy and macronutrient contents. Besides a zero condition [0.03 MJ (8 kcal)], there were three energy levels [0.42, 1.05, and 1.67 MJ (100, 250, and 400 kcal) combined with three dominant sources of macronutrients (99% of energy from CHO, 92% of energy from fat, and 77% of energy from protein). After breakfast the subjects were not allowed to eat or drink (except water) for 3.5 h. They then recorded their voluntary food intake for the remainder of the day. Subjects also rated their subjective feelings concerning food intake on five different types of appetite. The results showed that neither energy content or macronutrient composition of the liquid breakfasts had any effect on energy and macronutrient intake during lunch and the remainder of the day. Ratings of different types of appetite showed an increasing satiating effect with increasing energy content of the breakfasts. Proteins, fats and CHOs had similar effects on appetite.

INTRODUCTION

Of all the properties of food, energy appears to be the variable primarily responsible for the regulation of appetite.[1] Because the three main sources of energy in our food are carbohydrates, fats, and proteins, it is important to know whether or not there are differences in the satiating efficiency of these three macronutrients. The term satiating efficiency originates from Kissileff.[2] He argued that the satiating effects of various dimensions of food (e.g. volume, weight, viscosity) should be investigated systematically, by manipulating the level of one dimension of food, while holding the other dimensions constant. In such an experiment, subjects get different preloads with a varying level of a particular food dimension. Subsequently, subjects get a test-meal. Kissileff[2] defined the satiating efficiency of a particular food dimension as the extent to which that dimension is capable of reducing subsequent energy intake. He applied this strategy for assessing the satiating efficiency of liquid and solid foods[3], and various types of soups versus a combination of crackers, cheese and apple juice.[4] In this paper, the satiating effect of a food item is defined as the extent to which a certain food item is capable of influencing motivational ratings or subsequent energy intake.

Studies on the satiating effects of proteins, fats, and carbohydrates have fixed the energy content of a preload at one level of energy, while varying the macronutrient ratios within these preloads.[5-11] The satiating effect was established by measuring motivational ratings on food intake and by assessing subsequent energy intake.

With respect to motivational ratings, Geliebter[5], Driver[6] and Barkeling et al.[7] found no differences between the satiating effects of different macronutrients. Hill and Blundell[8,9] and Rolls et al.[10] found that the protein preloads were more satiating than carbohydrate or fat preloads. With respect to subsequent energy intake, Geliebter[5] found no differences, whereas Barkeling et al.[7], Hill and Blundell[9], and Rolls et al.[10] *found that energy intake in a subsequent meal was lower after the* high protein preload than after high-fat or high-carbohydrate preloads. Booth et al.[11] also concluded that calorie for calorie, protein was more satiating than fat or carbohydrates.

The differences in the results of the aforementioned studies may have resulted partly from the different energy levels of the preloads used. For an adequate description of the satiating effects of the macronutrients it is appropriate to assess dose-response relationships.[2] When dose-response relationships are assessed, it should be possible to express the magnitude of the effect of each macronutrient per unit of weight or energy. This enables a sound comparison between the satiating effects of different food dimensions.

The objective of this study was to investigate the satiating effects of proteins, fat, and carbohydrates by giving the subjects liquid breakfasts containing different ratios of the three macronutrients. The energy content was varied within each type of macronutrient. The description of different motivational concepts with respect to food intake were derived from unpublished observations (W Vaessen, JA Weststrate, and B de Boer, 1989) that feelings regarding food intake and appetite could be divided into four different types: 1) appetite for a meal, 2) appetite for a snack, 3) feeble, weak with hunger, and 4) a feeling of over-satiety or fullness. For the purpose of the present study, "appetite for a snack" was divided into "appetite for something sweet" and "appetite for something savoury".

METHODS AND MATERIALS

Subjects

The subjects were 29 female volunteers aged 19-23 y. Body mass indices (in kg/m^2) varied between 17.3 and 25.1 with a mean ($\pm$SD) of 21.1 $\pm$ 1.9. All the subjects were student at the Agricultural University and were paid for their participation. The subjects were informed that the experiment was being carried out to investigate the effect of different nutrients on feelings of hunger and satiety. They were not aware of receiving a particular treatment on a particular day. The experiment was approved by the Medical Ethical Committee of the Department of Human Nutrition.

Preloads

The 10 preload conditions consisted of 550-Ml solutions varying in energy and nutrient contents. There was one zero condition [0.03 MJ (8 kcal)], and the remaining nine conditions were composed according to a three-by-three factorial design. The first factor, energy, had three levels: 0.42, 1.05, and 1.67 MJ (100, 250, and 400 kcal). The second factor, macronutrient, also had three levels: carbohydrate, protein, and fat. Table 1 shows the macronutrient composition of the carbohydrate, protein, and fat preloads.

The nutrients were dissolved in a mixture of nine parts tap water to one part commercially available tomato juice, which was added in order to disguise textural differences. The carbohydrate preloads contained a commercially available diet product (Fantomalt, Nutricia, Zoetermeer, The Netherlands). According to the package, the product consisted in weight of 90% maltodextrine, 7% maltose, and 3% glucose. The protein preload contained a commercially available diet product (Protein 88, Wander, Uden, The Netherlands), reported to consist of 88% milk-protein and 12% water. To obtain an acceptable product from a sensory point of view, the protein was mixed with carbohydrates and fat. The fat preload contained commercially available cream (Slagroom, Melkunie, Woerden, The Netherlands).

Table 1. Macronutrient composition of different types of preloads.

Type of preload		
Carbohydrate	Protein	Fat
99 en% CHO	27 en% CHO	5 en% CHO
1 en% PRO	70 en% PRO	3 en% PRO
0 en% FAT	3 en% FAT	92 en% FAT

* Each type of preload was given at three energy levels, 0.42, 1.05,, and 1.67 MJ (100, 250, and 400 kcal). The 10th condition consisted of a zero preload that had an energy content of 0.03 MJ (8 kcal).

Measurements

Subjects characteristics with respect to eating behavior

All subjects completed the Dutch Eating Behavior Questionnaire (DEBQ) developed by van Strien[12], producing scores for restraint eating, external eating, and emotional eating.

Subjective feelings of hunger and satiety

The subjects were asked to express their feelings by means of a slash on five 150-mm visual-analogue scales: 1) appetite for a meal, 2) appetite for something sweet, 3) appetite for something savoury, 4) satiety (fullness), 5) feeble, weak with hunger.

One of each of these terms were placed above the centre of the five visual analogue scales, which were anchored at the left and right hand sides with the terms weak and strong, respectively.

The subjects were orally instructed, that appetite for a meal refers to appetite for a complete meal, either a hot meal or a sandwich meal. Appetite for something sweet is appetite for a sweet snack, eg, a cookie, chocolate, a candy bar, sweet pie, or a sweet dessert. Appetite for something savoury is appetite for peanuts, cheese, cocktail nuts, French fries, or a savoury dessert. Satiety (fullness) refers to a feeling of having eaten too much (a feeling many people experience at Christmas). Feeble, weak with hunger is a strong urge to eat.

Energy and nutrient intake

Energy and nutrient intakes were recorded by means of a food diary. The foods used for the evening meal were weighed to an accuracy of 2 g on electronic scales (Soehnle scalina, Soehnle-Waagen GMBH & Co, Murrhardt/Württ, FRG). The weights of the other foods consumed were estimated by means of standards for household measures. Each food diary for each day contained an instruction and five pages. The five pages were meant to record the amount of water consumed in the morning (page 1), the foods and drinks consumed at lunch (page 2), in the afternoon (page 3), at the evening meal (page 4) and in the evening (page 5). The scales were used for the evening meal only. In the Dutch diet lunch and snack items usually consist of standard food items, of which the weight can be accurately estimated by standard household measures. This is not the case for the foods and drinks at the evening meal.

The food diaries were checked and coded by experienced dieticians. Energy and nutrient intakes were calculated by using the Dutch food composition table.[13]

Sensory perception and pleasantness

Subjects rated the pleasantness, and the perceived intensity of the preloads on seven attributes: sweetness, saltiness, sourness, bitterness, viscosity, sandiness, and freshness. Ratings were made on 150-mm visual-analogue scales.

Procedures

The different preloads were offered in a random sequence and varied for each subject. Each subject received each preload on a different day, resulting in a within-subjects, repeated-measures design. The first experimental day was regarded as a practice day to accommodate subjects to the experimental procedure. The data obtained from this day were excluded from further analysis. The whole study lasted 6 weeks.

Subjects were invited to come to the laboratory between 0800 and 0900. They were asked not to eat or drink after 2300 the previous evening. The preload was consumed through a straw placed in a milk-shake beaker. During consumption subjects wore a noseclip, preventing them from detecting any differences in the odors of the different preloads.

Subjects were instructed to rate their feelings concerning the five types of appetite just before the consumption of the preload. Ratings in the morning were done after 15, 30, 45 min, and then every 30 min after the first rating. Sensory perception and pleasantness of the preload were rated just after consumption of the preload. Subjects were requested not to eat, and drink only water until 3 h 45 min after the first rating, just before consumption of the preload. After that time, subjects were instructed to eat whatever they felt like eating. Subjects recorded the food they consumed for the remainder of the day.

Data analysis

Ratings on the 150-mm visual-analogue scales for the appetite dimensions were read automatically by an Optical Mark Reader (Farrington Data Processing BV, Haarlem, The Netherlands) and were converted into scores from 1 to 25. A score of 1 corresponded to the left side of the scale (weak), a score of 25 corresponded to the right side of the scale (strong).

Statistical analysis for the effects of the preloads on energy and macronutrient intake and motivational ratings was carried out with repeated-measures analysis of variance (ANOVA)[14] by using the 8V module of the BMDP statistical software package.[15] The time and type of preload were fixed within subject factors. Subjects were treated as a random factor. With respect to characteristics on eating behavior, subjects were divided by a median split into groups with low and high scores of restraint and external and emotional eating. In this case, group was treated as a fixed between-subjects factor.

Relationships between motivational ratings and energy intake and between sensory ratings and motivational ratings were determined by using linear-regression analysis.

RESULTS

Feelings of hunger and satiety

The first ratings before consumption of the preload were set at zero for each of the different conditions. ANOVA showed that the type of preload had a significant effect on appetite for a meal [$F(9,252)=3.21$, $p<0.01$] appetite for something sweet [$F(9,252)=2.30$, $p<0.05$], appetite for something savoury

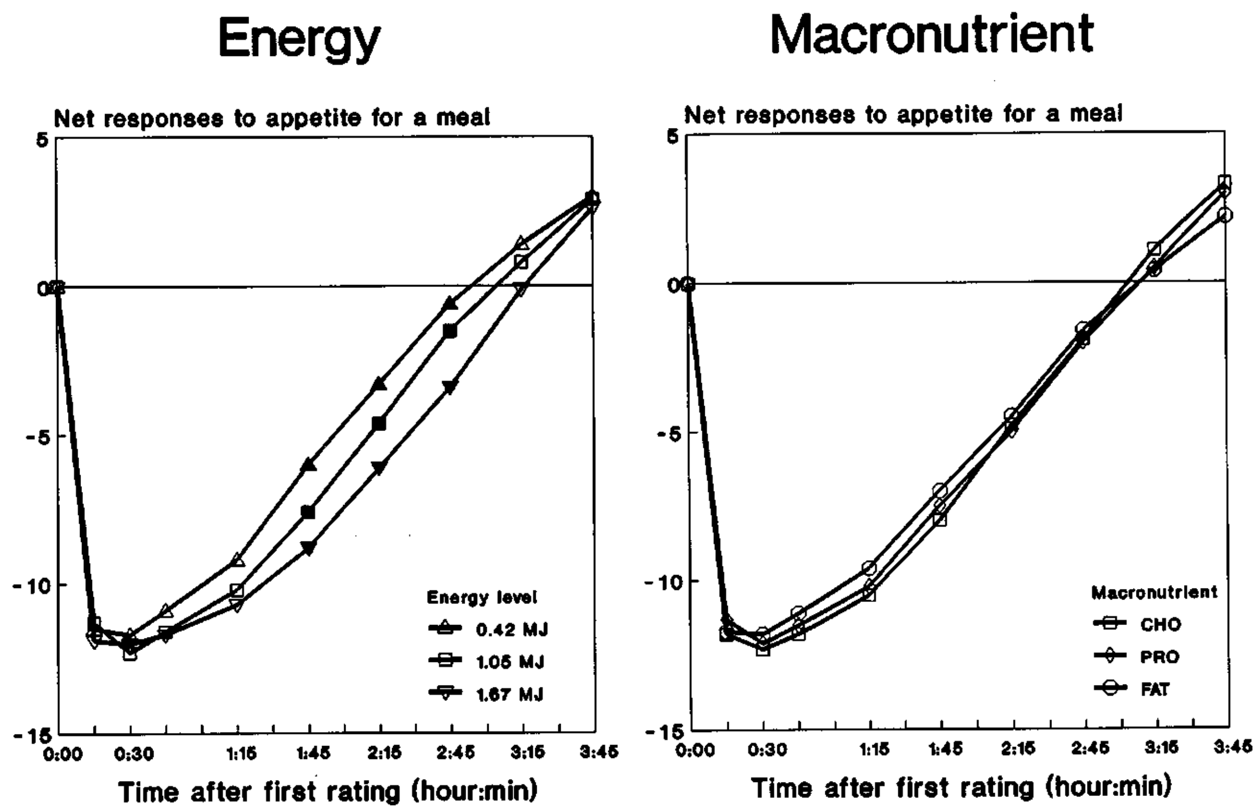

Figure 1. Net responses to appetite for meal as a function of time after the first rating. The first rating was made just before consumption of a liquid breakfast. Left panel: curves for each level of energy of the preloads averaged over type of macronutrient. Right panel: curves for the different types of macronutrient in the preloads averaged over energy levels. Filled symbols denote a significant difference between ratings, $p<0.05$.

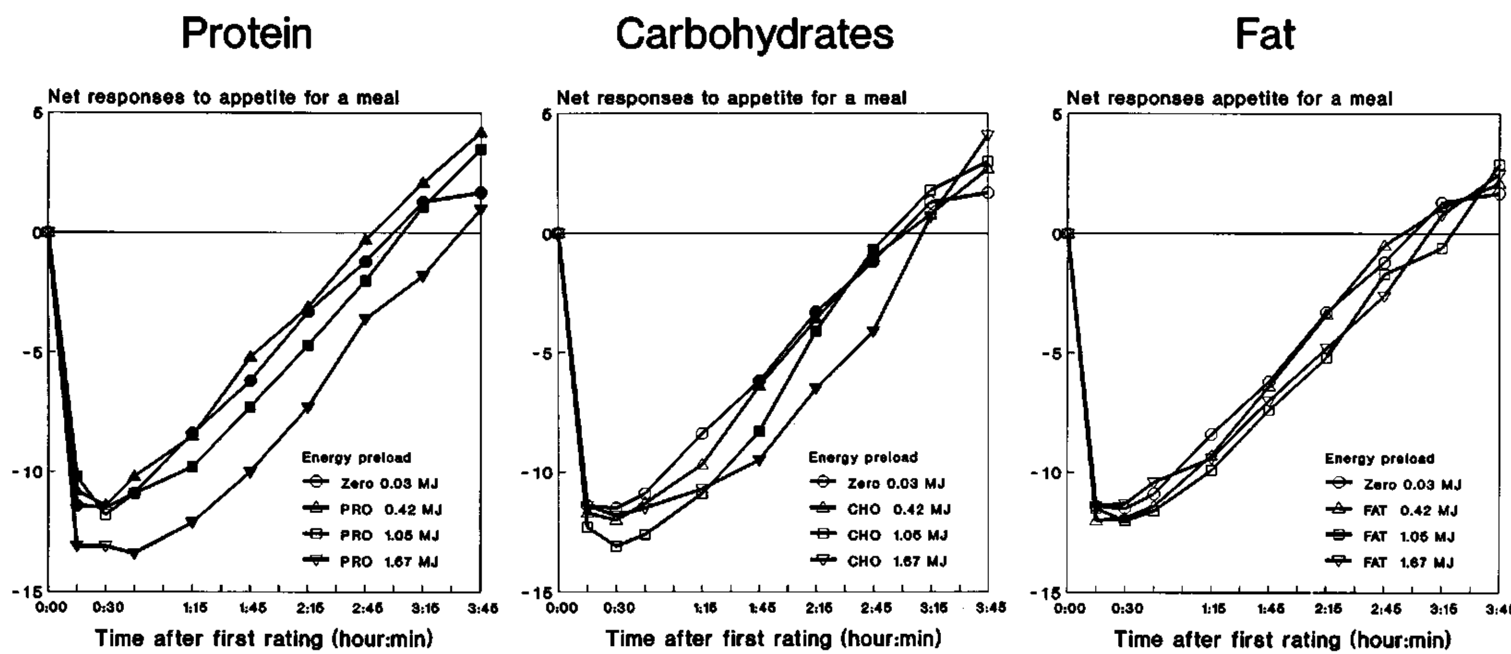

Figure 2. Net responses to appetite for a meal as a function of time after the first rating, with a separate curve for each level of energy. The first rating was made just before consumption of a liquid breakfast. left panel: protein preloads (77 en% PRO); middle panel: carbohydrate preloads (99 en% CHO); and right panel: fat preloads (92 en% fat). For reference, the response to the zero preload are shown in each of the three panels. Filled symbols denote a significant difference between ratings, $p<0.05$.

[F(9,252) = 7.70, $p<0.01$], satiety (fullness) [F(9,252) = 3.55, $p<0.001$], and feeble, weak with hunger [F(9,252) = 2.27, $p<0.02$]. Factor analysis with varimax rotation on the subjective ratings yielded one factor with an eigenvalue > 1, indicating that the responses to the five different types of appetite were strongly correlated. The responses to the five appetite dimensions were similar to one other. Because the variance in the ratings to appetite for a meal was larger than the variance to the other attributes, a detailed analysis is given for this dimension only. The responses and results for the other four types of appetite were similar to those for appetite for a meal.

The left-hand panel of Figure 1 shows the net responses to appetite for a meal averaged over the different macronutrient preloads, excluding the zero preload. ANOVA showed that the effect of energy level was significant [F(2,56) = 5.02, $p<0.01$]. ANOVAs carried out for each time separately, showed that the responses to appetite for a meal were different at 1.75, 2.25, and 2.75 h after the first rating. The right-hand side panel of Figure 1 shows the mean responses to appetite for a meal averaged over the different energy levels, also excluding the preload. ANOVA showed that the effect of the type of macronutrient is nonsignificant [F(2,56) = 0.25, $p>0.50$)]. Separate ANOVA's at each time yielded no significant differences. The net responses to carbohydrates, protein, and fat did not differ.

The three panels of Figure 2 show the net responses to appetite for a meal for each of the macronutrients as a function of the time after the first rating, with a different curve for each level of energy. ANOVA showed that the main effect of energy level (including the zero preload) was significant for the protein [F(3,84) = 12.1, $p<0.001$], but not for the carbohydrate [F(3,84) = 0.36, $p>0.5$] and fat [F(3,84) = 0.5, $p>0.5$] preloads. From these analyses the existence of a dose-response relationship for protein can be inferred. Appetite for a meal is lower after a preload with a higher energy content than after a preload with a lower energy content. With respect to carbohydrates, Figure 2 shows that compared with the zero preload the responses to appetite for a meal were lower for the first 2 h, but higher after 2.75 h. The responses to the 1.67 MJ (400 kcal) carbohydrates preload were lower than the responses after the other carbohydrate preloads at 1.75, 2.25, and 2.75 h after the first rating. The right-hand panel of Figure 2 shows that the responses to the different energy levels of the fat preloads were almost equal.

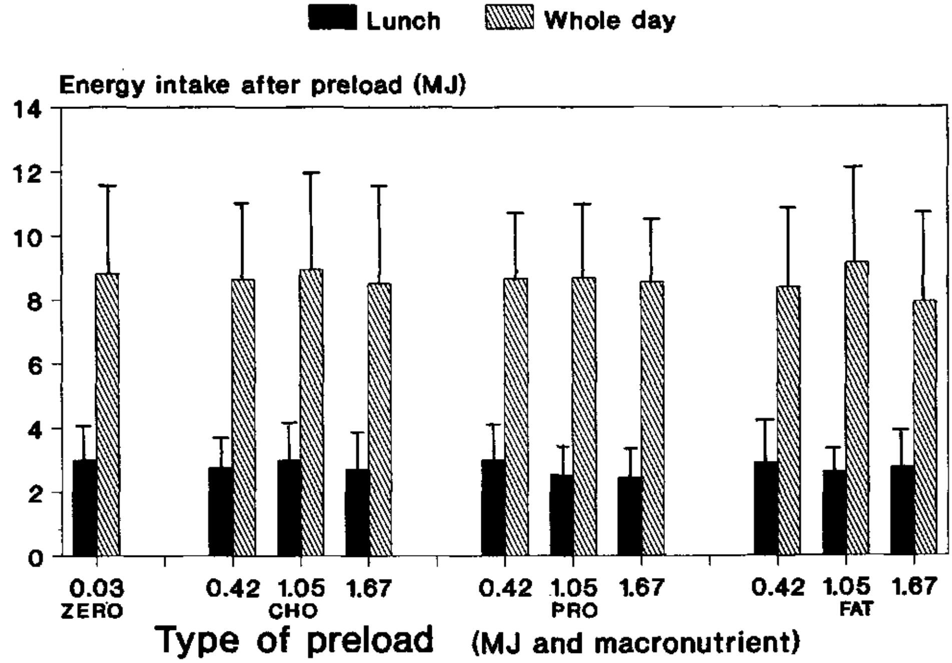

Figure 3. *Mean energy intake of 29 subjects at lunch and during the whole day* after consumption of liquid breakfasts with different energy and macronutrient contents. Subjects were not allowed to eat until 3.5 h after breakfast. The CHO-, PRO-, and FAT-preload types contained 99 en% carbohydrates, 77 en% proteins and 92 en% fat, respectively. $x \pm SD$.

Energy and macronutrient intake as a function of preload

Figure 3 shows the mean energy intake ($\pm$ SD) for lunch and the remainder of the day as a function of characteristics of the preload. Note that the energy intake of the preload itself is excluded. ANOVA showed that there were no differences in energy intake for the remainder of the day between the preload conditions [$F(9,252) = 0.76$, $p > 0.50$]. Energy intakes at lunch did not differ either [$F(9,252) = 1.57$, $p > 0.10$]. A two-way ANOVA with energy level and type of macronutrient as factors (zero condition excluded) showed no effect of energy or type of nutrient on the energy intake during the remainder of the day [Energy: $F(2,56) = 2.30$; $p > 0.10$/ Nutrient: $F(2,56) = 0.25$, $p > 0.50$].

Figure 4 shows the amounts of different macronutrients consumed after the different preloads, during the whole day. No effect of preload was found for any of the macronutrients. The F(9,252)-ratios for carbohydrates, fats, protein and alcohol were respectively, 1.15, 0.90, 0.90, and 0.74 (all p-values > 0.05). The average and range of SDs of the weights of macronutrients consumed during the whole day were 74 g (49-91) for carbohydrates, 33 g (23-41) for fats, 22 g (16-29) for protein, and 17 g (10-31) for alcohol. The macronutrient content of the lunch was also independent from the type of preload. The F(9,252)-ratios for carbohydrates, fats, and proteins were, respectively, 0.75, 1.34, and 1.82 (all p>0.05). No alcohol was consumed during lunch.

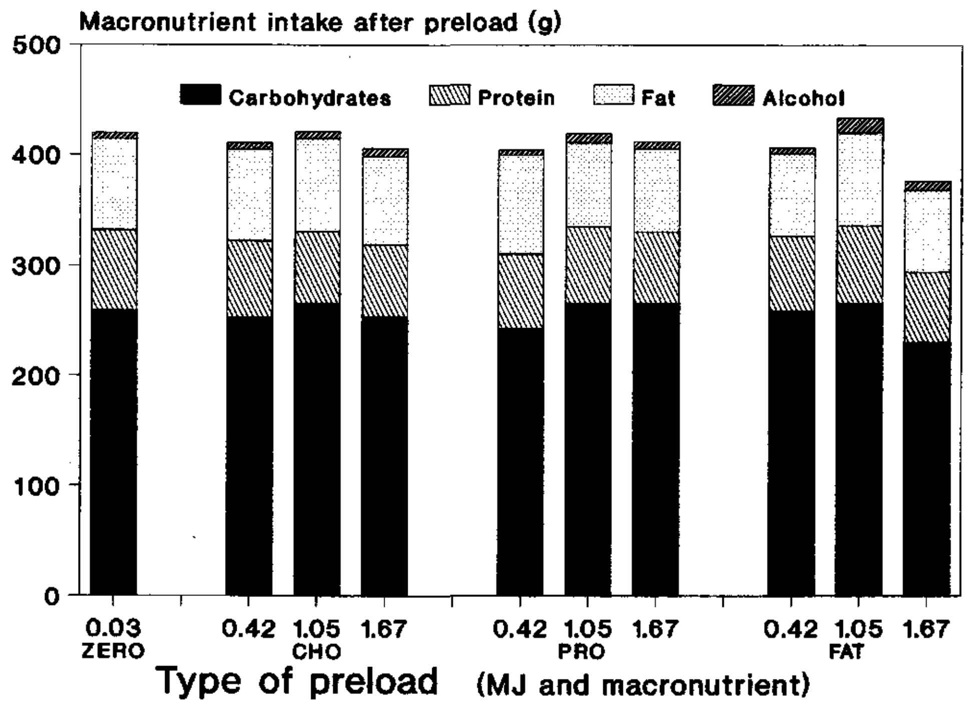

Figure 4. Mean macronutrient intake of 29 subjects during the remainder of the day after consumption of liquid breakfasts with different energy and macronutrient contents. Subjects were not allowed to eat until 3.5 h after breakfast. The CHO-, PRO-, and FAT-preload types contained 99 en% carbohydrates, 77 en% proteins, and 92 en% fat, respectively. For information on standard deviations, see text.

Energy intake as a function of eating behavior characteristics

Compared with van Strien's[12] Dutch female reference population, the median value for external eating for the subjects who participated in the present study could be classified as average. The median values for restraint and emotional eating could be classified as above average. An ANOVA was carried out to compare the energy intakes for the groups with low and high scores on the emotional, external, and restraint factors. None of these factors had a significant effect on the energy intake during the whole day [Emotional: $F(1,26)=0.40$, $p>0.5$; External: $F(1,26)=0.60$, $p>0.5$; Restraint: $F(1,26)=0.07$, $p>0.5$].

Sensory ratings of the preloads

The sensory profile of the preloads differed in all dimensions. All $F(9,252)$ ratios were > 2.50 with a probability < 0.01. The sweetness and pleasantness of preloads may exert an influence on motivational ratings and subsequent energy intake[16,17]. Therefore there was an investigation as to whether the sweetness and pleasantness ratings correlated with the motivational ratings at 2.75 h after the first rating, and with the energy intake at lunch, and energy intake during the whole day. The motivational ratings at 2.25 h were chosen, because the differences in ratings between conditions were largest 2.25 h after the first rating.

The ratings of pleasantness did not correlate with energy intake at lunch [$r(288)=0.08$, $p>0.05$) or energy intake during the remainder of the day [$r(288)=-0.02$, $p>0.05$]. Sweetness ratings also did not correlate with energy intake at lunch [$r(288)=-0.03$, $p>0.05$] or with energy intake during the remainder of the day [$r(288)=0.03$, $p>0.05$]. The only significant correlations between sweetness, pleasantness, and the motivational ratings were those between sweetness and satiety [$r(288) = 0.17$, $p < 0.01$], and between pleasantness and appetite for something sweet [$r(288) = -0.20$, $p < 0.01$].

Motivational ratings before lunch and energy intake at lunch

About 96% of the lunches were consumed between 1200 and 1400. Depending on the time of the breakfast, subjects were allowed to eat again between 1145 and 1245. The responses to the motivational ratings at 3.75 h after the first rating, which were in most cases just before lunch, correlated significantly with energy intake at lunch. The correlations were 0.32 for appetite for a meal, 0.28 for appetite for something sweet, 0.40 for appetite for something savory, -0.23 for satiety (fullness), and 0.33 for feeble, weak with hunger. All correlation coefficients had a probability < 0.01.

DISCUSSION

The main conclusion from these results is that subjects did not compensate for the energy taken in at breakfast. They did not eat more after a preload with a low energy content [0.03 MJ (8 kcal)] than after a preload with a high energy content [1.67 MJ (400 kcal)]. The nutrient composition of the preloads had no influence on the energy intake during lunch and the remainder of the day. No shift occurred in the consumed amounts of carbohydrates, proteins and fats. Thus, after a high-carbohydrate preload, the subjects consumed just as much carbohydrates as after a high-protein or a high-fat preload. Similar results were found for protein and fat consumption.

Although the preloads had no effect on intake, they did have an effect on motivational ratings. After a high energy intake in the preload, ratings of appetite were lower than after a low energy intake. Differences between ratings emerged 1 h after consumption of the preload, were highest between 1.75 h and 2.75 h, but disappeared after 3.75 h after consumption of the preload. The disappearance of differences in motivational ratings after 3.75 h explains why no differences were found in energy intake at lunch.

The results of this study generally agree with the results of other studies on the satiating effects of the different macronutrients.[5-11,18,19] However, some specific results differ. The present results concur with those of Geliebter[5], Driver[6] and Barkeling et al.[7], who also found that the three macronutrients had similar effects on feelings of hunger and satiety. In contrast, the studies of Hill and Blundell[8,9], and of Rolls et al.[10] found that protein had a larger effect on motivational ratings than did fats and carbohydrates.

Barkeling et al[7], Hill and Blundell[9], and Rolls et al.[10] found that subsequent energy intake was lower after a protein preload than after fat or carbohydrate preloads. These results do not agree with the present findings. It appears that the present findings are more in line with those of Geliebter[5] and Sunkin and Garrow[18] who also found that energy intake after a protein preload was not lower than after fat or carbohydrate preloads. Foltin et al.[19] did not find any difference in the effect on energy intake between high-fat and high-carbohydrate lunches. In that study, however, subjects ate less after a high-energy lunch than after a low-energy lunch.

The present finding that different macronutrient preloads did not result in differences in subsequent macronutrient consumption concurs with the results of Rolls et al.[10]

The differences between the results of various studies may be explained by methodological differences in experimental setup. One issue is the time between preload and test meal or ad libitum food-intake. In the present study the subjects were not allowed to eat after consumption of the breakfast preload until lunch time. Two h after the preload consumption there were differences in motivational ratings; for instance, subjects had a greater appetite for a meal after a low-energy preload than after a high-energy preload. The significant correlations between motivational ratings before lunch and energy intake at lunch suggests that, if subjects had been allowed to eat after 2 h, the result of the present study might have been different. In the experiments of Rolls et al.[10] and Hill and Blundell[9], the protein preload was more satiating than carbohydrate or fat preloads. The higher satiating effects of protein was apparent from both the motivational ratings and the subsequent energy intake in a test meal. In these experiments the test meals were given 2-3 h after the preload. The time between preload and ad libitum food intake in the present study was almost 4 h. As Figures 1 and 2 show, this is an important difference. Apparently the time between the preload and test meal is a crucial variable in determining whether or not energy compensation occurs.

Similar remarks can be made with respect to the time of the preload. In the present study, the subjects were given breakfast. Would the results have been different they had been given lunch or dinner instead of breakfast? The results of Barkeling et al.[7] and Foltin et al.[19], in which subjects got lunch, suggest that this can be an important variable. The present study lasted only 1 day. If we had given the subjects similar preloads for a number of consecutive days, would the subjects then have compensated for the amount of energy in the preload? If so, at what time would they have started compensating? The results of Louis-Sylvestre et al.[20] suggest that subjects learn about the consequences of preloads within 5 days. Similarly, in the present study, subjects were given liquid, bland-tasting artificial preloads; in that sense our preloads were similar to those of Geliebter.[5] In the other studies discussed, subjects were given normal food items. In the present study subjects did not compensate for a [1.67 MJ (400 kcal)] difference in preload. At what level of energy difference between the preloads would they start to compensate?

These questions show that the results and conclusions of this study might be limited to the specific experimental conditions used. Regarding the complexity of the issue, it appears that a careful and systematic evaluation of all potential influences is required to assess the factors that regulate appetite and food intake. This idea is equivalent to Kissileff's[2] strategy of determining satiating effects of various dimensions of foods.

ACKNOWLEDGEMENTS

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CHAPTER 3

THE EFFECTS OF PRELOADS VARYING IN PHYSICAL STATE AND FAT CONTENT ON SATIETY AND ENERGY INTAKE.

Toine Hulshof, Cees de Graaf, Jan A. Weststrate.

ABSTRACT

This study investigated the effect of the physical state and fat content of a preload on feelings of hunger and satiety and subsequent energy intake. Thirty three normal-weight female subjects each received 9 different 550-ml preloads which were served as breakfast. The preloads differed in physical state and fat level. There were three types of physical state (liquid, solid with locust bean gum, and solid with gelatin) combined with 3 energy levels (0.42, 1.67, and 3.35 MJ). The energy differences were due only to differences in fat content. Subjects were not allowed to eat or drink (except water) for 3½ hr after preload consumption. In this period they rated their feelings of appetite. Subjects recorded their voluntary food intake for the remainder of the study day and the day after the study day. There were no effects of the different amounts of fat or the three different physical states on energy intake the remainder of the day or the day after. With respect to the appetite ratings, however, it appeared that the solid preloads were more satiating than the liquid preloads and the solid preloads were more satiating with fibre (locust bean gum) than without fibre (gelatin). The high-fat preloads were more satiating than the low-fat preloads.

INTRODUCTION

Among the properties of food that influence its satiating effect, the structure/consistency of a food is important. A priori it seems plausible that solid foods have a different effect on appetite than liquid foods. The digestion and absorption of solid foods is more prolonged than of liquid foods (BNF, 1990). Therefore, it can be expected that solid foods suppress appetite for a longer time period than liquid foods.

There is no consistent evidence that solid foods are more satiating than liquid foods. Haber et al. (1977), Bolton et al. (1981) and Tournier et al. (1991) obtained results that suggest that solid preloads are more satiating than liquid preloads. Kissileff (1985) and Rolls et al. (1990) obtained results in the opposite direction, whereas Pliner (1973) found no effects.

Table 1 shows that apart from differences in the physical state (liquid versus solid), the preloads also differed with respect to macronutrient content (Pliner, 1973; Kissileff, 1985; Rolls et al., 1990), volume (Pliner, 1973; Bolton et al., 1981; Kissileff, 1985) and temperature (Kissileff, 1985; Rolls et al., 1990). Some of the solid preloads were accompanied by a drink (Kissileff, 1985; Rolls et al., 1990; Tournier et al., 1991). Therefore it is difficult to attribute differences in satiating effect in these experiments to the different physical states. Tournier et al. (1991) and Haber et al. (1977) had solid and liquid preloads with an identical composition.

The present study investigated the effect of the physical state with standardized artificial preloads equal in volume, weight, temperature, and with equal protein and carbohydrate content. In order to find out whether the effect of physical state is similar for different levels of energy, three different amounts of fat were added to the preloads. The purpose of the study was to investigate whether differences in fat content and/or physical state of preloads influence feelings of hunger and satiety and energy intake in a short-term dose response experiment. A carbohydrate (Locust bean gum) and a protein (Gelatin) were used for changing the consistency of the preloads. Locust bean gum added to a meal slows the emptying of liquids from the stomach (Holt et al., 1979). Gums increase the viscosity in the gut and reduce macronutrient absorption probably by inhibiting the convective effects of intestinal contractions (Edwards et al., 1988). Gelatin dissolves in the stomach immediately after consumption (Tournier et al., 1991), and therefore no effect of the solid state of gelatin on the rate of macronutrient absorption in the gut can be expected.

In this study the liquid preloads were ingested and digested as a liquid. The locust bean gum preloads were ingested and digested as a solid, whereas the gelatine preload was ingested as a solid and digested as a liquid (Tournier et al., 1991). With this design the difference between the gelatin preloads and the liquid preloads should be due to the difference in ingestion, whereas the difference between the locust bean gum and gelatin preloads should be due to differences in digestion and absorption.

Table 1. Liquid and solid foods used in experiments in which the effects of the physical state on the satiating efficiency was investigated.

Author	Year*	Liquid preload	Solid preload
Pliner P.	1973	- Milk shake.	- Cake.
Haber G. et al.	1977	- Apple juice.	- Apple quarters.
Bolton R.	1981	- Grape juice. - Orange juice.	- Whole grapes. - Oranges.
Kissileff H.	1984	- Chicken noodle or tomato soup.	- Cheese, crackers and apple juice.
Rolls B. et al.	1990	- Tomato soup plus water (225 ml).	- Cheese on crackers plus water (225 ml). - Melon plus water.
Tournier A. et al.	1991	- Vegetable soup, and tomato juice with liquid gelatin.	- Vegetable terrine plus gelatin), and tomato juice.

* Year of publication

METHODS AND MATERIALS

Subjects

Thirty-three female volunteers with a BMI < 25 kg/m^2 were recruited for participation. All subjects were students at the Agricultural University, and were paid for participation. Table 2 shows the main characteristics of the subjects.

The subjects were informed that the experiment was meant to investigate the effect of different preloads on feelings of hunger and satiety. The differences in physical state were clearly recognized by the subjects. Post experimental briefing revealed that the subjects were not aware of the differences in energy/fat content of the preloads. All subjects gave their informed consent before participation. The experiment was approved by the Medical Ethical Committee of the Department of Human Nutrition.

Table 2. Main characteristics of the 33 female subjects.

	Mean	(sd)	Range
Age (years)	21.4	(1.7)	19 - 26
Height (cm)	172.3	(6.6)	156 - 185
Weight (kg)	62.8	(5.7)	50 - 75
B.M.I. (kg/m^2)	21.1	(1.5)	18.4 - 24.2
Restraint eating score*	2.7	(0.8)	1.1 - 4.0
External eating score*	3.2	(0.4)	2.2 - 3.8
Emotional eating score*	2.6	(0.5)	1.5 - 3.6

* According to the Dutch Eating Behavior Questionnaire of Van Strien (1986).

Preloads

The nine different preloads of 550 ml varied in physical state and energy (fat) content. The preloads were composed according to a 3 X 3 factorial design. Physical state was the first factor with three levels: liquid, solid by carbohydrate (locust bean gum), solid by protein (gelatin). The second factor was energy level, with three levels: 0.42 MJ (100 kcal), 1.67 MJ (400 kcal), and 3.35 MJ (800 kcal). The differences in energy were only due to differences in fat content, with 0 g, 33 g, and 77 g fat added to the 0.42 MJ, 1.67 MJ, and the 3.35 MJ preload respectively. Table 3 shows the macronutrient composition of the nine different preloads. The solid locust bean gum preloads were made with 12 g Nutriton which is a commercially available thickening agent. This product contains more than 87 g locust bean gum per 100 g (Nutricia, Zoetermeer, The Netherlands). The other solid preloads were made with 8 g gelatin (Baukje bakprodukten B.V., Rijssen, The Netherlands). Commercially available cream (Slagroom of Melkunie, Woerden, The Netherlands) was used to manipulate the fat content of the preloads. A carbohydrate diet product (Fantomalt) and a protein diet product (Protein 88) were used to get equal carbohydrate and protein amounts in the nine preloads. Fantomalt (Nutricia, Zoetermeer, The Netherlands) consists of 90, 7 and 3 % by weight of maltodextrin, maltose and glucose respectively. Protein 88 (Wander, Oss, The Netherlands) consists of 94 % of the energy as milk protein, 4 % fat and 2 % carbohydrates.

Table 3. Macronutrient content of the nine preloads, varying in consistency and energy content.

Preload	Physical state	Energy content (MJ)	FAT (g)	FAT (%)*	CHO (g)	CHO (%)*	Protein (g)	Protein (%)*
1	Liquid	0.42	0	(1)	13	(51)	12	(48)
2	Liquid	1.67	33	(75)	13	(13)	12	(12)
3	Liquid	3.35	77	(87)	13	(7)	12	(6)
4	Solid: LBG	0.42	0	(1)	13	(51)	12	(48)
5	Solid: LBG	1.67	33	(75)	13	(13)	12	(12)
6	Solid: LBG	3.35	77	(87)	13	(7)	12	(6)
7	Solid: gelatin	0.42	0	(1)	13	(51)	12	(48)
8	Solid: gelatin	1.67	33	(75)	13	(13)	12	(12)
9	Solid: gelatin	3.35	77	(87)	13	(7)	12	(6)

CHO = Carbohydrate; LBG = Locust bean gum; * = Percentage of energy.

Measurements

Eating behaviour characteristics of the subjects.

Before the experiment started all subjects completed the Dutch Eating Behaviour Questionnaire (DEBQ) developed by van Strien et al. (1986), producing scores for restraint eating, external eating and emotional eating.

Ratings of hunger and satiety

Feelings of hunger and satiety were rated by means of a slash on five 150-mm lines labelled:

1: appetite for a meal;
2: appetite for something sweet;
3: appetite for something savoury;
4: satiety (fullness);
5: feeble/weak with hunger.

One each of these terms was placed above the centre of each of the five lines, which were anchored on the left- and right-hand side with the terms weak and strong, respectively.

Written and oral instructions were provided to inform the subjects about the meaning of these terms. "Appetite for a meal" refers to appetite for a complete meal, either a hot meal or a sandwich meal. "Appetite for something sweet" is appetite for a sweet snack, i.e., a biscuit, chocolate, a candy bar, sweet pie or a sweet dessert. "Appetite for something savoury" is appetite for peanuts, cheese, cocktail nuts, french fries, or a savoury dessert. "Satiety (fullness)" refers to a feeling of having eaten too much (a feeling many people experience after the Christmas dinner). "Feeble, weak with hunger" reflects a strong urge to eat.

Energy and nutrient intake

Energy and nutrient intake were recorded by means of a food diary. All the foods and drinks consumed during the evening meal were weighed to an accuracy of 2 g on electronic scales (Soehnle scalina, Soehnle-Waagen GMBH & Co, Murrhardt/Württ, Germany). The weight of the other foods consumed during the day were estimated by means of standards for household measures. Every food diary for each day contained an instruction and five pages. The five pages were meant to record the amount of water consumed during the morning (page 1), and the foods and drinks consumed at lunch (page 2), in the course of the afternoon (page 3), the evening meal (page 4) and in the course of the evening (page 5). The electronic scales were used for the evening meal only. In the normal Dutch diet, lunch and snack items usually consist of standard food items, of which the weight can be accurately estimated by standard household measures. This is not the case for the foods and drinks at the evening meal.

The food diaries were checked and coded by experienced dieticians. In case of unclear food records subjects were asked about this by the dietitians within a week. Energy intake was calculated using the Dutch food composition table (Nevo, 1986).

Sensory perception and pleasantness

Subjects rated the pleasantness and the perceived intensity of the preloads according to seven attributes: sweetness, saltiness, sourness, bitterness, viscosity sandiness, and freshness. Ratings were made on 150-mm lines, anchored on not at all and extremely.

Procedure

The different preloads were offered in a random sequence, that varied for each subject. A test day was run before the first study day to familiarize the subjects with all the procedures of the experiment. Every subject received each preload on a different day, resulting in a within-subjects repeated measures design. Study days were always on Tuesdays and Thursdays to eliminate weekend effects. The whole study lasted six weeks.

Subjects were invited to come to the laboratory between 0800 and 0900 hrs. They were asked not to eat or drink anything except water after 2300 hrs the previous evening. The liquid preload was consumed through a straw placed in a covered milkshake beaker. The solid preloads were presented in the same milkshake beaker but were consumed with a spoon. During consumption of both the liquid and the solid preloads subjects wore a nose-clip, preventing them from detecting any differences in the odours of the different preloads.

Subjects were instructed to rate their feelings of hunger and satiety on the 5 ratings just before the consumption of the preload. Further ratings were made 15, 45, 105, 165 and 225 minutes after the first rating. Sensory perception and pleasantness of the preload were rated just after consumption of the preload. From the first rating till the rating at 225 minutes subjects were not allowed to eat or drink (except water). This was done to enable the temporal tracking of motivational ratings for a long period without interference of food consumption. After this deprivation period subjects were instructed to eat and drink whatever they wanted. For the energy intake after preload consumption on the study day (day 1) and the day after the study day (day 2) subjects recorded all the food and drinks in the food diary.

Data analysis

Ratings of hunger and satiety were read by an Optical Mark Reader (OMR) and converted into scores from 1 (weak) to 25 (strong).

To enable one overall comparison of the effects of the nine different preloads on motivational ratings, the area under the curve (AUC) was taken as the dependent variable (instead of the 6 scores on motivational ratings). One advantage of the area under the curve is that it gives one value, so that the effect of preloads can be compared directly with each other (instead of comparing curves). Another advantage is that this measure takes into account the magnitude of the different time intervals between the adjacent measurements (which is not the case in ANOVA).

The disadvantage of this analysis is that the temporal tracking of the hunger and satiety feelings is missed. This is the reason why in analysis involving the factor time we used the absolute ratings and not the area under the curve. The area under the curve was calculated as percentage of the total area by the following equation (see figure 1):

$$(((1/8\ (A+3B+6C+8D+8E+4F))-3\tfrac{3}{4})/90)*100,$$

where A, B, C, D, E, F, are the motivational ratings at 0, 15, 45, 105, 165, and 225 min, respectively. The lower the AUC value for "appetite for a meal", the more satiating the preload is.

Statistical analysis for the effects of the preloads, the factor physical state, or the factor fat level on area under the curves with respect to feelings of hunger and satiety and energy intake were carried out with ANOVA for repeated measures using the SAS statistical software package (SAS Institute inc., 1990). The type of preload was the fixed within-subject factor, and subjects were the random factor. When the interaction of a factor with time was calculated, ANOVA was performed on the absolute responses of appetite ratings. The effect of eating behaviour characteristics on energy intake was determined by ANOVA with a division in three tertiles as independent variable.

Pearson's correlation coefficients were used to investigate relationships between motivational ratings just before lunch and energy intake at lunch. Linear regression analysis (least squares) was performed to determine the slopes between the motivational ratings and energy intake (with 297 observations pairs), and between restraint eating score and energy intake (with 33 observation pairs).

The effects of the preloads were similar for all five appetite feelings (with opposite results for "satiety (fullness)"). As "appetite for a meal" is conceived as being similar to general hunger, we only present the results for this dimension (de Graaf et al., 1992).

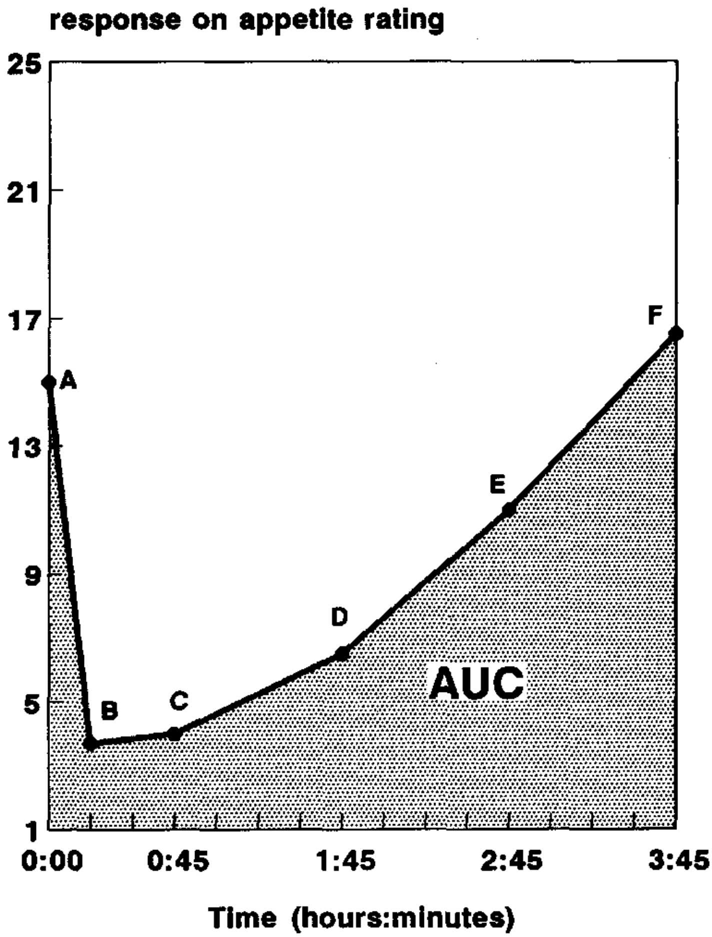

Figure 1. Illustration of the calculation of the area under the curve (AUC), using absolute appetite values. The AUC is calculated as the surface under the curve ((1/8(A+3B+6C+8D+8E+4F))-3¾) divided by the total area (3¾*24=90) multiplied by 100%. The result gives the area under the curve in percent of the total area.

RESULTS

Feelings of hunger and satiety as a function of preload

There were clear differences in values of area under the curve for "appetite for a meal" between the nine different preloads [$F(8,256) = 22.88$, $p < 0.0001$].

When comparing the effects of the three physical states, significant differences for "appetite for a meal" ratings were found [$F(2,64) = 25.80$, $p < 0.0001$], with the locust bean gum preload reducing "appetite for a meal" the most (20% AUC), followed by gelatin (28% AUC) and the liquid preload (35% AUC). This consistency effect was found for all three energy (fat) levels separately (figure 2) with [$F(2,64) = 15.96$, $p < 0.0001$], [$F(2,64) = 7.62$, $p < 0.002$], [$F(2,64) = 14.88$, $p < 0.0001$] for the 0.42 MJ, 1.67 MJ, and 3.35-MJ preloads respectively.

Clear differences were found between the three energy (fat) levels [$F(2,64) = 50.86$, $p < 0.0001$] with the 3.35-MJ preload reducing "appetite for a meal" the most (19% AUC), followed by the 1.67-MJ (27% AUC) and the 0.42-MJ preload (37% AUC). This energy effect was found for in all three consistency levels with [$F(2,64) = 12.85$, $p < 0.0001$], [$F(2,64) = 16.13$, $p < 0.0001$], [$F(2,64) = 35.44$, $p < 0.0001$] for liquid, locust bean gum and gelatin respectively (figure 2).

At the different energy levels, different magnitudes in satiating effects of the three different consistencies were found, meaning that there was a significant interaction between energy level and consistency, [$F(4,128) = 2.54$, $p < 0.05$], with larger differences in area under the curve for the gelatin preloads.

Figure 3 illustrates the time course effects of the physical state of the foods on ratings of "appetite for a meal" (averaged over the three energy levels). Immediately after the preload consumption, the locust bean gum preloads suppressed "appetite for a meal" more than the gelatin and the liquid preloads, whereas the gelatin preload was more suppressive than the liquid preload. This is the case for every measurement over the period until lunch. The differences between the liquid and the locust bean gum preload were smaller just after the preload consumption (2.5 units) than just before lunch (4.1 units). This finding is confirmed by a statistically significant interaction between time and consistency [$F(10,320) = 3.98$, $p < 0.0001$].

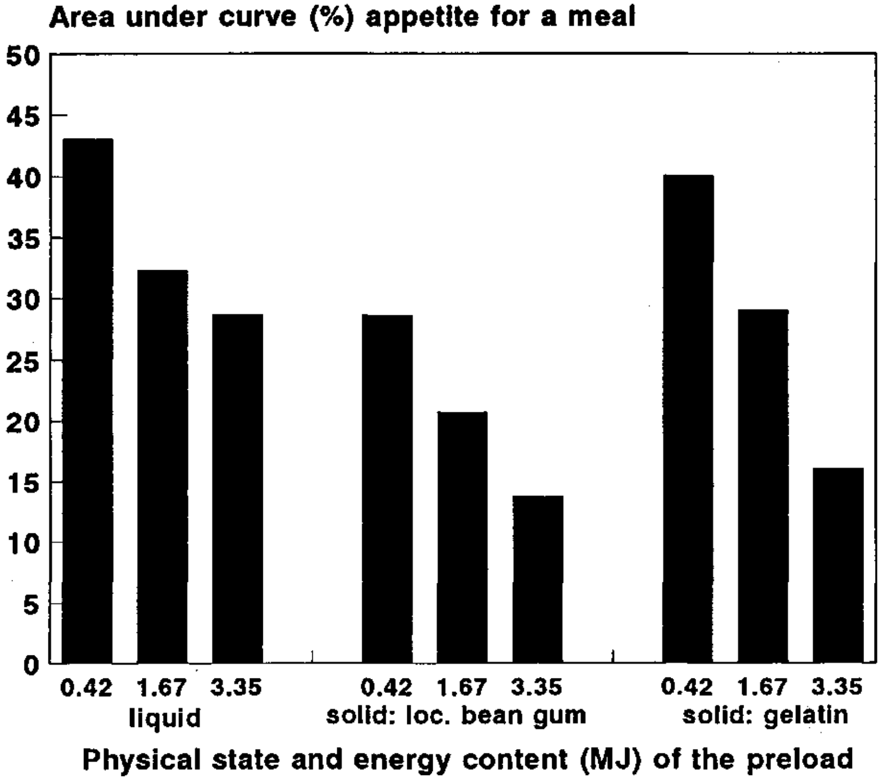

Figure 2. Area under the curve (AUC) as percentage of the total area values calculated over a period of 3¾ hours for all nine preloads for "appetite for a meal". The preloads were given as breakfast, followed by a deprivation period during which the subjects were not allowed to consume food until 3¾ hours after the appetite ratings made just before preload consumption.

Figure 4 shows the time course effect of the different energy (fat) levels on "appetite for a meal" (averaged over the three physical states). Immediately after the preload consumption, the higher energy preload suppressed "appetite for a meal" more than the lower energy preloads. This was seen for the entire period from preload consumption till lunch, but with larger differences just before lunch (7.0 units) compared to just after preload consumption (2.0 units). This is also confirmed by the interaction between time and energy (fat) level [$F(10,320) = 16.51$, $p < 0.0001$].

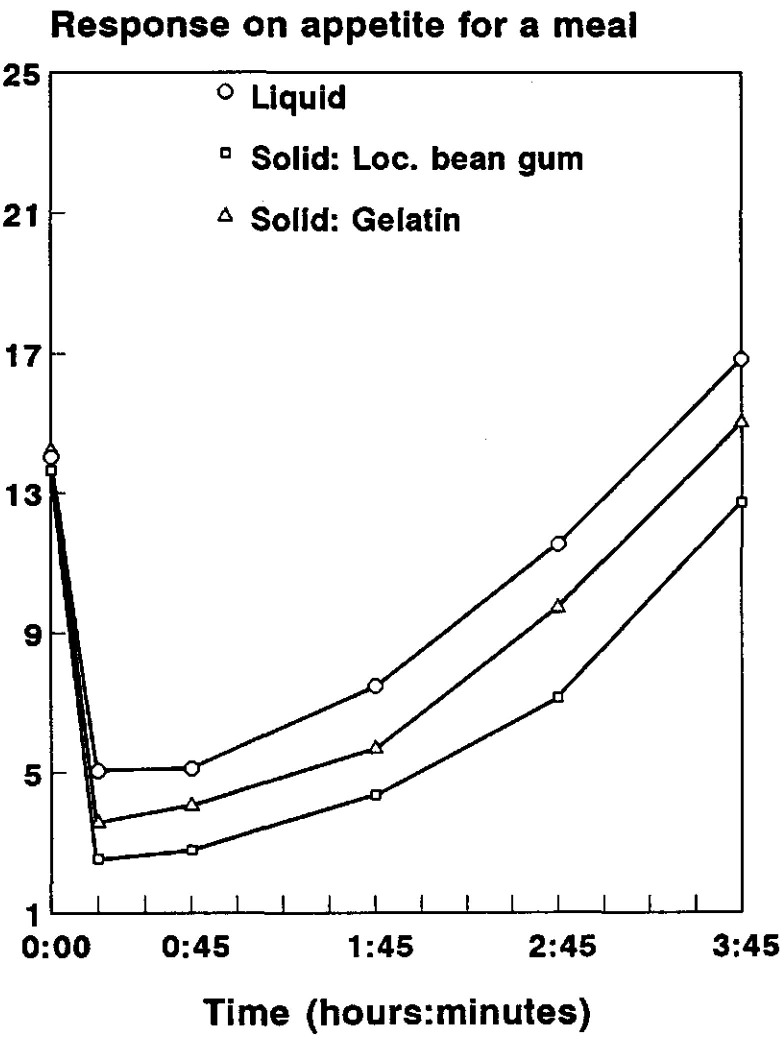

Figure 3. The effect of physical state of the preload on "appetite for a meal" as a function of time. The first rating was made just before the consumption of the preload at breakfast time.

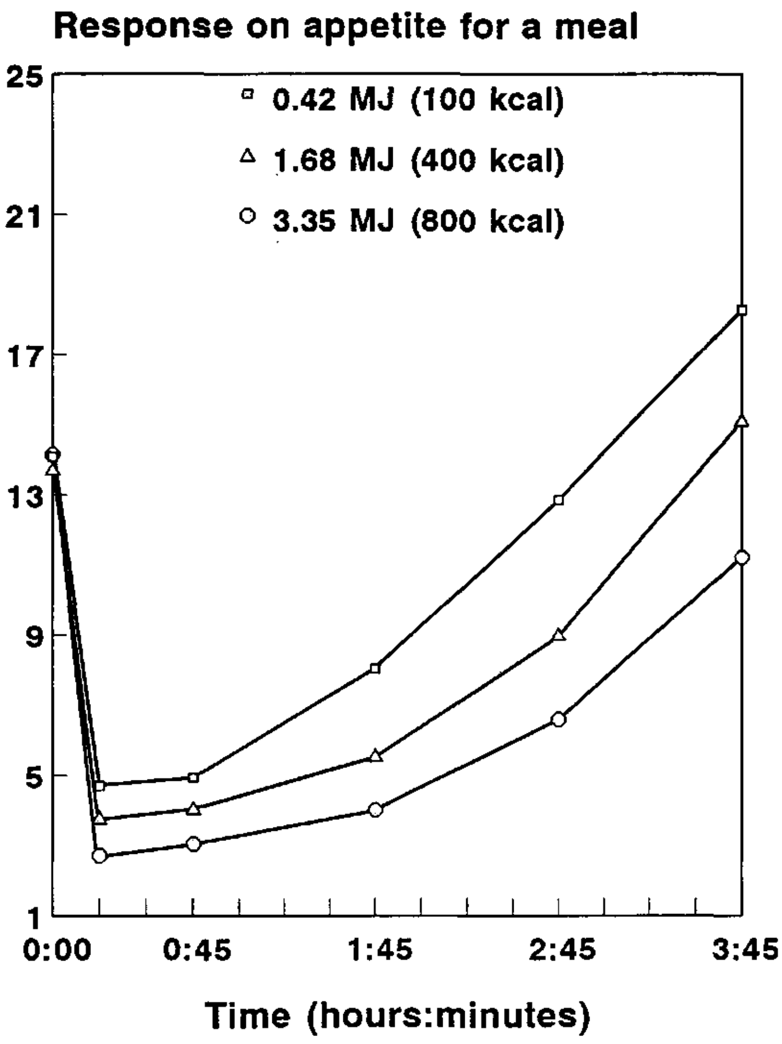

Figure 4. The effect of energy level of the preload on "appetite for a meal" as a function of time. The first rating was made just before the consumption of the preload at breakfast time.

Table 4. Mean and standard deviation (sd) of the energy intake at lunch of day 1, the energy intake on day 1 (without preload energy), and the total energy intake of day 2, for the nine different preloads.

Preload	Energy intake					
	Lunch day 1		Day 1		Day 2	
	MJ	(sd)	MJ	(sd)	MJ	(sd)
Liquid 0.42 MJ	2.77	(1.02)	8.56	(2.16)	8.84	(2.65)
Liquid 1.67 MJ	2.43	(0.93)	8.52	(2.51)	9.33	(2.42)
Liquid 3.35 MJ	2.24	(0.93)	8.17	(2.08)	9.47	(2.57)
L.B.G. 0.42 MJ	2.64	(1.00)	8.40	(2.95)	8.95	(2.85)
L.B.G. 1.67 MJ	2.55	(0.90)	8.47	(2.48)	8.95	(2.35)
L.B.G. 3.35 MJ	2.08	(0.78)	8.22	(2.42)	8.93	(2.43)
Gelatin 0.42 MJ	2.56	(0.98)	8.44	(2.79)	9.31	(2.19)
Gelatin 1.67 MJ	2.18	(0.83)	8.04	(2.14)	9.08	(1.95)
Gelatin 3.35 MJ	2.51	(1.20)	8.59	(2.39)	9.27	(2.29)

L.B.G. = Locust bean gum

Energy intake as a function of preload

The mean energy intake at lunch, the energy intake of the study day without the preload energy (day 1), and the total energy intake the day after the study day (day 2) as a function of the nine preloads are shown in Table 4. There were no significant differences in energy intake between the nine different experimental conditions on day 1 or on day 2 with [$F(8,256) = 0.27$, $p > 0.1$] and [$F(8,256) = 0.39$, $p > 0.1$] for day 1 and day 2 respectively. There was no effect of consistency on energy intake on day 1 or on day 2 with [$F(2,64) = 0.03$, $p > 0.1$] and [$F(2,64) = 0.53$, $p > 0.1$] for day 1 and day 2 respectively. No energy (fat) effect existed on energy intake on day 1 [$F(2,64) = 0.13$, $p > 0.1$] or day 2 [$F(2,64) = 0.31$, $p > 0.1$].

For energy-intake at lunch of day 1 significant differences were found between the nine different preloads [$F(8,256) = 2.46$, $p < 0.05$]. This effect was due to the different energy levels of the preloads [$F(2,64) = 5.02$, $p < 0.01$] and not because of differences in consistency [$F(2,64) = 0.23$, $p > 0.1$]. Only the liquid and locust bean gum preloads showed the energy effect of higher energy intake after the lower energy preload with [$F(2,64) = 3.34$, $p < 0.05$] and [$F(2,64) = 5.40$, $p < 0.01$] respectively, but not gelatin [$F(2,64) = 1.49$, $p > 0.1$].

Table 5. Mean values for energy intake on day 1, day 2, and lunch of day 1 for the three tertiles of restraint eating score, and regression equations for the effect of restrained eating on energy intake.

	Tertile of Restrained Eating		
	Low (n=11)	Medium (n=11)	High (n=11)
Restraint score (DEBQ)	1.7	2.7	3.6
Age (years)	21.5	21.4	21.4
Height (cm)	174	170	172
Weight (kg)	61.0	62.6	64.8
B.M.I. (kg/m^2)	20.1	21.5	21.8
Intake at lunch day 1 (MJ)	2.72	2.48	2.12
Intake on day 1 (MJ)#	9.20	8.49	7.44
Intake on day 2 (MJ)	10.01	9.21	8.16

Regression equations for the effect of restrained eating on energy intake (n=33):

Intake at Lunch dat 1 (MJ)	= 3.03 - 0.223*RS	(r = -0.50)
Intake on day 1 (MJ)#	= 10.37 - 0.746*RS	(r = -0.34)
Intake on day 2 (MJ)	= 11.35 - 0.833*RS	(r = -0.47)

RS = Restraint score according to the DEBQ of Van Strien (1986).

Note that the energy of the preloads is not included.

Table 6. The regression equations for the effect of motivational ratings just before lunch on energy intake at lunch (n=297).*

Lunch (MJ) = 1.94 + 0.0337*Appetite for a meal	(r = 0.25)
Lunch (MJ) = 2.11 + 0.0267*Appetite for something sweet	(r = 0.20)
Lunch (MJ) = 1.95 + 0.0370*Appetite for something savoury	(r = 0.28)
Lunch (MJ) = 2.12 + 0.0365*Feeble, weak with hunger	(r = 0.26)

* The ratings on motivational ratings ranged from 1 (weak) to 25 (strong).

Energy intake as a function of eating behaviour characteristics

The mean scores on the Dutch Eating Behaviour Questionnaire (DEBQ) were 2.7 for restrained, 3.2 for external and 2.6 for emotional eating behaviour. Compared to the Dutch female population these values are above average, high and above average for restrained, external and emotional eating behaviour respectively. No differences were found in energy intake on day 1, day 2, or lunch of day 1 between the three tertiles of emotional and external eating [All $F(2,30) < 0.69$, all $p > 0.50$]. Clear differences were found between energy intake on day 1, day 2 and lunch of day 1 between the three tertiles of restrained eating with [$F(2,30) = 8.40$, $p < 0.05$], [$F(2,30) = 5.79$, $p < 0.05$] and [$F(2,30) = 4.11$, $p < 0.05$] for energy intakes of day 1, day 2 and lunch of day 1 respectively (Table 5). Energy intake decreased with increasing restraint scores.

Sensory ratings of the preloads

The sensory profile of the three consistencies differed in sweetness, sandiness, viscosity, freshness and pleasantness [all $F(2,64) > 9.42$, and all $p < 0.001$]. Large differences were found for sandiness with a score of 44 mm for the locust bean gum preloads and 9 mm and 12 mm for the liquid and gelatin preloads respectively. Viscosity was rated high for the locust bean gum and the gelatin preloads with 91 mm and 67 mm respectively and low for the liquid preloads with a rating of 14 mm. The liquid preloads had the highest pleasantness ratings (67 mm) followed by the gelatin preloads (45 mm) and the locust bean gum preloads (20 mm). The 1.67-MJ and the 3.35-MJ preloads were equally rated for pleasantness (40 mm and 41 mm respectively) whereas the 0.42-MJ preload was rated somewhat higher (51 mm).

Motivational ratings before lunch and energy intake at lunch

Positive correlations ($P < 0.001$) were found between the motivational ratings 3¾ after the first rating (just before lunch) and the energy intake at lunch for "appetite for a meal" ($r297 = 0.25$), "appetite for something sweet" ($r297 = 0.20$), "appetite for something savoury" ($r297 = 0.28$) and "feeble, weak with hunger" ($r297 = 0.26$). For "satiety (fullness)" no significant correlation was found ($r297 = -0.09$, $p = 0.11$). Table 6 shows the regression equations for the effect of motivational rating just before lunch on the energy intake at lunch. Higher energy intakes at lunch were found after higher appetite ratings just before lunch (except for "satiety (fullness)".

DISCUSSION

The main conclusion to be drawn from this experiment is that with the methodology used solid preloads were more satiating than liquid preloads. This was true for each of the three energy/fat levels used. The preloads thickened with the locust bean gum were more satiating than the preloads thickened with gelatin. These clear differences in appetite ratings between the three physical states did not result in differences in energy intake.

The conclusion that solid preloads have a higher suppressive effect on feelings of appetite than equivalent liquid preloads reinforces the findings of Haber et al. (1977) and Bolton et al. (1981). Tournier et al. (1991) and Rolls et al. (1990) did not find different suppressive effects on feelings of appetite between liquid and solid preloads whereas in the experiments of Kissileff (1985) and Pliner (1973) no ratings on appetite were made. So, with respect to feelings of appetite, all published studies have shown that solid preloads are equally or more satiating than liquid preloads.

The gelatin preload was more satiating than the liquid preload. This difference is probably due to differences in the way these foods were digested. The gelatin preload was eaten with a spoon, whereas the liquid preload was ingested by means of a straw. This result suggests that differences in methods of ingesting a food such as the consumption of liquid products with a straw, or straight from a bowl, or eating with a spoon, knife and fork, or with the hands, could cause differences in the satiating effect of products. In this experiment subjects needed no mastication for the solid preloads as they had to in all six experiments listed in table 1. During mastication, processes involved in appetite and energy intake regulation could also be influenced.

The locust bean gum preload was more satiating than the gelatin preload. This is probably due to differences in digestion and absorption, and not because of differences in ingestion. Although it is known that fibre increases the satiating effect of products (Burley et al., 1989), it is yet unclear to which magnitude fibre affects the found difference between the locust bean gum and gelatin preload.

Kissileff (1984) states that when one is investigating the properties of food which contribute to satiety, the interval between preload and test meal should be kept as short as possible. He also states that when a long interval is imposed between the preload and test meal, one is no longer studying the satiating efficiency of a food, but rather the combined effects of the food load and deprivation. It was decided to investigate the effects of the physical state in an environment as close as possible to the normal life situation of the subjects. A short deprivation period after a rather large breakfast (average of 1.8 MJ in 550 ml) would not be considered as normal. Therefore, the deprivation period was from breakfast till lunch, only leaving out the coffee break in between. In this way the temporal tracking of appetite could be studied for several hours.

Another issue in the study of appetite is the way food intake is measured. Food intake in a test meal in a laboratory can be observed and measured more accurately than it can be measured by using reported intake of subjects. However, food intake in a test meal disrupts the normal eating pattern to a greater extent than the recording of food intake in a food diary. A test meal forces people to consume food at a particular time and place. In this study, by using a food diary, people were not restricted in their eating behaviour after the deprivation period. As the subjects didn't notice differences between the preloads within one physical state they couldn't act in a logical way to influence their food consumption. It is true that the subjects knew what physical state they were eating, but the physical state is by definition known by a subject when a product is eaten. As we were interested in the differences between the preloads and not in the absolute values of energy intake, we think that a food diary is very suitable for the design used, as no systematically differences can be expected.

Differences in feelings of hunger and satiety were also found between the three energy/fat levels. There is a clear dose-response effect between energy content and ratings of hunger and satiety, with lower ratings after the high energy preload, and this relation counts for all three consistencies (with the largest differences between the gelatin preloads and the smallest differences between the liquid preloads). De Graaf et al. (1992) found no statistically significant differences in appetite scores between liquid preloads with different amounts of fat, in a study with a similar experimental design. This can be explained by the fact that in that study liquid preloads with a maximal difference in energy level of 1.26 MJ (300 kcal) were used and not 2.93 MJ (700 kcal) like in the present study. Another reason could be that in de Graaf et al. (1992) the appetite ratings were calculated in a slightly different way as compared to this study. When the absolute appetite ratings after the liquid 0.42 MJ and the liquid 1.67 MJ preloads in the study of de Graaf et al. (1992) and this study are examined, comparable differences between the curves were found.

Although the differences in ratings of hunger and satiety between the preloads were very clear, no effect was found on the energy intake of day 1 or day 2. Only a small but significant decrease in energy intake at lunch on the study day from 2.65 MJ for the 0.42-MJ preload to 2.27 MJ for the 3.35-MJ preload was found. In the experiment of de Graaf et al. (1992) no differences were found in energy intake at lunch after a deprivation of 3½ hours. It is surprisingly that even in the present study with a difference of 2.93 MJ (700 kcal) between the low and high energy preload, no effect on energy intake was found. In the study of de Graaf et al. (1992) it could be explained by the fact that the differences in appetite ratings had become equal after 3½ hours. Yet in the present study the differences in appetite ratings were even larger after 3½ hours after preload consumption. It seems that, when subjects are not aware of an energy manipulation, they eat the same the remainder of the day after different energy loadings when a long suppression period is included.

Tournier et al. (1991) found no difference in energy intake at dinner after liquid and solid preloads consumed at lunch time. In that study subjects were not allowed to eat or drink for 3½ hours after preload consumption as in the present study. The results of Kissileff (1985), Pliner (1973), and Rolls (1990) in which the effects of a preload on a test meal was investigated are not in line with the present findings. The deprivation period between the preload and test meal in Kissileff's (1985) and Rolls' (1990) studies was less then 15 min, and 1 hour in the study of Pliner (1973). Whether a test meal is eaten directly after the preload consumption or eaten after 3½ hours could strongly influence the results on energy intake. It could be that solid preloads are more satiating than liquid preloads after a long delay, but less satiating than liquids after a short delay.

The pleasantness of the preloads varied from not pleasant for the locust bean gum preload to neutral for the liquid preload. We do not think that the pleasantness of meals has an independent effect on feelings of appetite. There is no theoretical basis for the notion that the palatability of a food, which is consumed within a short period, has an effect on appetite feelings or ratings, several hours after consumption. We think that palatability has a large effect on satiation, i.e. the process of getting sated during a meal, and not on satiety, i.e. the state of being sated after a meal. Thus it is likely that palatability has an effect on the ad libitum consumption during a meal, but not on a the energy intake in a lunch several hours later.

We conclude that there are substantial differences between the satiating effect of liquid and solid preloads. The physical state can act as a strong confounder on the results in studies that investigate the satiating efficiency of properties of foods. This should be taken into consideration when making the choice for a preload.

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CHAPTER 4

THE EFFECTS OF COVERT CHANGES IN THE AMOUNT OF FAT AND A NON-ABSORBABLE FAT (SUCROSE POLYESTER) IN CROISSANTS, ON FOOD INTAKE AND APPETITE.

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ABSTRACT

This study investigated the effects of the consumption of preloads with three energy levels (1.66, 2.53 and 3.39 MJ), due to different amounts of fat and the fatreplacer sucrose polyester (SPE), on appetite and subsequent food intake. Each of the three preloads was consumed at three different times of the day (at 0800, 1230 and 1500 hrs). All nine different experimental conditions were given to 33 normal weight subjects. Every preload consisted of two and a half croissant with ham and cheese. The results showed that no compensation in energy intake was found after the three different energy levels of the preloads, for any of the three times of preload consumption. As a result, the percentages energy from fat, when considering the total energy intake of day 1, decreased from 46% for the 3.35 MJ preloads to 40% and 34% for the 2.53 and 1.66 MJ preloads. On day 2 no differences in intake were found. On day 1 higher total energy intakes were found compared with day 2, when the preloads were consumed at 1500 hrs. With respect to feelings of appetite, different patterns were found for the three different times of preload consumption, but not for the three energy levels. In conclusion, covert changes in the amount of fat or non-absorbable fat (SPE) in croissants did not influence appetite feelings or energy intake after preload consumption.

INTRODUCTION

In the Netherlands, as in other developed countries, the average total fat intake is too high (Hulshof et al. 1991). From a perspective of health an overconsumption of fat or energy is related to many diseases like obesity, NIDDM, heart disease and cancer (Seidell et al. 1987). Compared to the 37 energy percent from fat, which was consumed in the Netherlands in 1992 (Löwik et al. 1993), the recommended fat intake is between 30 and 35 percent (Voedingsraad 1989). Therefore efforts have to be made to reduce the dietary fat intake.

Fat replacers like sucrose poly-ester (SPE) can be used to reduce the fat and the energy content of food products. SPE is a non-caloric fat replacer made from chemically linking of sucrose molecules with fatty acids, derived from edible oils of fats. It has a similar appearance, and the same physical and sensory properties as normal dietary fat, but it is not digested and absorbed in the human body (Fallat et al. 1976). One of the major issues regarding the use of fat replacers in food products, is whether or not this replacement results in compensation in fat or energy intake. SPE can only be a useful tool to reduce fat or energy intake, when no complete energy or fat compensation occurs. When energy compensation is complete, but no specific fat compensation occurs, SPE will decrease the percent energy derived from fat in the food. In the latter case SPE still can help to achieve the recommended intake for fat.

Up till now four experiments on the satiating power of SPE have been published. Rolls et al. (1992) and Blundell et al. (1992) investigated in a replication study the effects of three preloads at breakfast with different amounts of fat replaced by SPE (0, 20 and 36 g) on food intake. In the lunch test-meal after three hours no differences in energy intake were found. In the dinner test-meal and during the evening the subjects compensated for the energy differences in the preload at breakfast, with as a result that the total energy intake of that day did not differ. In both studies no specific compensation in fat intake was found after the different preloads, resulting in a decrease in percentage energy from fat, when the fat was replaced by SPE.

Birch et al. (1993) investigated 29 children between 2 and 5 years old. They were given either normal foods or foods with SPE at breakfast, during the morning and at lunch. The energy intake was recorded for the study day and the day after the study day. They found that after an average replacement of 14 g SPE for fat (0.52 MJ), the children had compensated 48% of the energy difference at the end of day one, and 81% at the end of day 2. As no macronutrient compensation occurred after the manipulated food intake, a decrease in energy from fat for the total intake on the study day was observed.

In a study of Glueck et al. (1982) seven obese women and three obese men were investigated for 20 days in a row repeated twice. In one period the subjects got a placebo diet, in the other period fat was replaced by on average 60 g SPE.

In this longer term study on average 13% of the energy deficit obtained by replacing fat by SPE was compensated for. The percentage energy from fat went down from 43% in the placebo diët to 28% in the SPE diet.

Between these four studies different results were found with respect to energy intake, but in all studies the fat intake went down. The differences in energy intake could be due to differences in the methodologies used. First there were differences in the amount of SPE used. Second the subjects were different, with lean young men or children in the three short term studies, and obese middle aged men and women in the longer term study. Third the short term studies of Rolls et al. (1992) and Blundell et al. (1992) had a preload test-meal design, whereas in the study of Birch et al. (1993) and Glueck et al. (1982) the manipulation was given in certain food products during the day. Fourth, there was a difference in the number of days during which the SPE manipulation was investigated.

In studies on the satiating effects of products or meals, sometimes the preloads were given at breakfast time (e.g. Burley et al. 1987, Hulshof et al. 1993), often at lunch time (e.g. Rolls et al. 1989, Caputo et al. 1992) and sometimes at times where normally no meal would be consumed (e.g. Brala et al. 1983, Anderson et al. 1989). Up till now there have been no investigations on the effects of preload consumption at different times of the day on energy compensation after the preload consumption.

The main objective of this study was to investigate whether covert changes in sucrose poly-ester and fat influence feelings of appetite and subsequent food intake in relation to time of day. There were three different times of the day at which the preload was consumed: breakfast preload at 0800 hrs, lunch preload at 1230 hrs, and afternoon preload at 1500 hrs. In the breakfast and lunch preload conditions the preload replaced one of the meals on a day, whereas the afternoon preloads did not.

METHODS AND MATERIALS

Subjects

Seventeen male and sixteen female volunteers, between 19 and 25 years old, participated in the study. Subjects with a BMI larger than 25 kg/m^2 or a restraint score over the 80-th percentile (> 2.37 for men, > 3.24 for women) on the Dutch Eating Behaviour Questionnaire (Van Strien 1986) were excluded for participation. All subjects were students at the Wageningen Agricultural University, and were paid for participation. Every subject signed an informed consent before participation in the study. The subjects were told that the experiment was meant to investigate the effect of meals on feelings of hunger and satiety, and that there was a possibility that SPE was used in the preloads. Post experimental briefing revealed that the subjects were not aware of the nature of the substances used. The experiment was approved by the Medical Ethical Committee of the Department of Human Nutrition. Table 1 shows the main characteristics of the subjects of this study.

Table 1. Main characteristics of the subjects

	Men (n = 17)		Women (n = 16)	
	Mean	(sd)	Mean	(sd)
Age (years)	22	(2)	22	(2)
Height (cm)	184	(5)	171	(7)
Weight (kg)	71	(7)	64	(7)
BMI (kg/m^2)	21	(2)	22	(3)
Fat percentage (%)*	14	(4)	24	(5)
Restrained eating score†	1.5	(0.4)	2.5	(0.7)

* Calculated with the biceps + triceps skinfolds and the formula of Durnin and Womersley (1974).

† The restrained eating score was measured with the DEBQ of Van Strien (1986). The minimum value is 1 (no restraint) and the maximum value is 5 (high restraint).

Preloads

There were nine experimental conditions, composed according to a three times three factorial design. Energy was the first factor with three levels: 1.66 MJ (395 kcal), 2.53 MJ (605 kcal), and 3.39 MJ (810 kcal). The time of preload consumption was the second factor with three levels: 0800 hrs, 1230 hrs, and

1500 hrs. Every preload consisted of two and a half croissants spread with (low fat) margarine, and with (low fat) ham or (low fat) cheese. The total weight of the preloads was approximately 170 gram. The energy content of the croissants was predominantly manipulated by varying the fat content, by adding extra fat or by replacing fat with SPE. In the low fat croissants (1.66 MJ) 21 gram SPE was used, instead of 21 gram margarine as in the control croissants (2.53 MJ). In the high fat croissants (3.35 MJ) 31 gram margarine was used. The croissants were baked in the bakery of Unilever Research Laboratorium Vlaardingen (the Netherlands), and kept frozen until the day of consumption. The spread, ham, and cheese were commercially available products, bought in a local supermarket. Table 2 shows the energy and macronutrient composition of the three different preloads.

Table 2. Energy and macronutrient composition of the two and a half corissants spread with ham and cheese.

Preload	Weight	Energy	Macronutrients			
			FAT	Protein	CHO	SPE
	g	MJ (kcal)	g (E%)	g (E%)	g (E%)	g (E%)
Low fat	170	1.66 (395)	13 (30)	22 (22)	48 (49)	21 (0)
Control	170	2.53 (605)	35 (53)	22 (15)	48 (32)	0 (0)
High fat	170	3.39 (810)	64 (72)	18 (9)	38 (19)	0 (0)

E% = Percentage energy derived from the specific macronutrient.

Measurements

Eating behaviour characteristics of the subjects.

Before the experiment started all subjects completed the Dutch Eating Behaviour Questionnaire (DEBQ) developed by van Strien (1986), producing scores for restrained eating, external eating and emotional eating.

Subjective feelings of hunger and satiety

Subjective feelings of hunger and satiety were rated by means of a slash on five 150 mm visual analogue scales as described by Hulshof et al. (1993). In this study only the ratings of "appetite for a meal" will be presented, as in a former study "appetite for a meal" described general hunger best (de Graaf et al. 1992). The term "appetite for a meal" was placed above the centre of the visual analogue scale, which was anchored on the left and right hand side with the terms weak and strong, respectively.

Written and oral instructions were provided to inform the subjects about the meaning of the terms. "Appetite for a meal" referred to appetite for a complete meal, either a hot meal or a sandwich meal.

Energy and nutrient intake

Energy and nutrient intake were recorded by means of a food diary. All the foods and drinks consumed during the evening meal were weighed to an accuracy of 2 g on electronic scales (Soehnle scalina, Soehnle-Waagen GMBH & Co, Murrhardt/Württ, Germany). The weight of the other foods consumed during the day were estimated by means of standards for household measures. In the normal Dutch diet, lunch and snack items usually consist of standard food items, of which the weight can be accurately estimated by standard household measures. This is not the case for the foods and drinks at the evening meal.

The food diaries were checked and coded by experienced dieticians. In case of unclear food records subjects were asked about this by the dietitians within a week. Energy and nutrient intake were calculated using the Dutch food composition table (Nevo, 1986).

Sensory perception and pleasantness

Subjects rated the pleasantness and the perceived intensity of the ham and cheese croissants for nineteen attributes on 150 mm visual analogue scales. Visual attractiveness of the croissant was rated before preload consumption. The remaining attributes were rated during the consumption of the croissants. The main attributes were: sweetness, saltiness, sourness, bitterness, greasiness, crispness, and croissant-taste. Table 3 shows the attributes for the three energy levels, averaged for the ham and cheese croissant values per energy level.

Table 3. The pleasantness and eight sensory attributes for the three differenct energy levels rated on 150 mm visual analogue rating scales, with values averaged for the ham and cheese croissant.

Attribute	Energy level of the preload		
	1.66 MJ (mm)	2.53 MJ (mm)	3.39 MJ (mm)
Visual attractiveness	70	97	92 *
Sweetness	43	46	46
Saltiness	52	52	60
Sourness	28	27	28
Bitterness	26	23	24
Croissant taste	50	64	73 *
Crispness	33	43	56 *
Greasiness	48	54	95 *
Pleasantness	76	63	56 *

* Statistically significant differences betweeen the three energy levels $p<0.05$ (F 2,64).

Procedure

The different preloads were offered in a random sequence, that varied for each subject. Two test days were run before the first study day, to familiarize the subjects with all the procedures of the experiment. Every subject received each preload on a different day, resulting in a within-subjects repeated measures design. Study days were always on Tuesdays and Thursdays to eliminate weekend effects. Subjects were asked not to eat or drink anything, except water, after 2300 hrs the day before the study day. The whole study lasted for six weeks.

On the study day subjects arrived at the departmental dining room five minutes before 0800, 1230, or 1500 hrs, depending on the time of preload consumption. No food intake was allowed before 0800 hrs, when preload consumption was at 0800 hrs. When the preloads were consumed at 1230 or 1500 hrs, subjects were asked to consume their habitual diet before preload consumption. This habitual food consumption was talked over with a dietitian and written down before the study started. The subjects were asked to consume this diet consistently to avoid differences in food intake before the preload consumption. Deviations from their habitual diet had to be reported to the dietitians.

Subjects were instructed to rate their appetite feelings every clock hour of the study day from 0800 till 2100 hrs. Additional ratings were made just before the consumption of the preload and 15, 30, 60, 90, 120, 150, 180 and 210 minutes after that rating. Sensory perception and pleasantness of the preload were rated just before and during the consumption of the preload. From the rating just before preload consumption till the rating at 210 minutes after preload consumption subjects were not allowed to eat or drink (except water). After this period subjects were instructed to eat and drink whatever they wanted. For the remainder of the study day (day 1) and the day after the study day (day 2) subjects recorded all the food and drinks in the food diary.

Data analysis

Ratings on "appetite for a meal" were read by an Optical Mark Reader and converted into scores from 1 (weak) to 25 (strong). Analyses were done on the absolute values of "appetite for a meal".

ANOVA for repeated measures (SAS statistical software package; SAS Institute inc., 1990) was used to analyze the effects of the nine experimental conditions or the three energy levels (fat levels), on appetite values, energy and macronutrient intake. The type of preload was the fixed within subject factor, and subjects were the random factor. Percentages of energy derived from the macronutrients were calculated as the mean of the individual values.

Energy compensation was calculated as the negative slope of the line between the three levels of preload energy and the ad lib energy intake after the preload consumption, as was described by Kissileff (1984). The mean of the individual regression coefficients was tested against a slope of zero. A slope of -1 indicates 100% energy compensation whereas a slope of -0.2 indicates 20% energy compensation.

We are aware that the total intake of the study day is composed of both the dependent (ad libitum intake) as the independent (obligatory intake) aspects of the intake variable. However, as bodyweight is regulated by the total amount of energy intake, we investigated whether the time of preload consumption had an effect on total energy intake. As no effects of the nine experimental conditions on the energy intake of day 2 occurred, day 2 was regarded as a reference day. ANOVA for unequal cell sizes (GLM procedure of the SAS statistical software package; SAS Institute inc., 1990) was used to compare the total energy intake of each of the nine experimental conditions of day 1 with the mean total energy intake of day 2.

RESULTS

Energy intake as a function of the energy level of the preload.

Table 4 shows the mean energy intake on the study day (day 1) and the day after the study day (day 2) at six different periods of the day for the nine different experimental conditions.

The preload at 0800 hrs replaced the subjects' normal breakfast. After the 0800 hrs preloads no differences in energy intake were found at any of the periods of day 1 between the three energy levels of the croissants preloads (all $F(2,64) < 2.65$, $p's > 0.08$). At the end of day 1, subjects had consumed 9.12 MJ, 9.11 MJ and 8.69 MJ after the 1.66, 2.53 and 3.35 MJ preloads respectively, the differences were not statistically significant [$F(2,64) = 0.49$, $p = 0.62$]. On day 2 the only period "during the morning" showed statistically significant higher intakes after the lower energy levels of the preloads [$F(2,64) = 3.44$, $p = 0.04$]. The other periods of day 2 showed no differences [all $F(2.64) < 1.83$, $p's > 0.17$]. At the end of day 2 the subjects had consumed 20.71, 19.76 and 19.38 MJ after the 1.66, 2.53 and 3.35 MJ preloads respectively [$F(2,64) = 1.29$, $p = 0.28$].

The croissant preload at 1230 hrs replaced the subjects' normal lunch. After the 1230 hrs preloads no differences in energy intake were found at any of the periods of day 1 or day 2 between the three energy levels of the preloads [all $F(2,64) < 0.98$, $p's > 0.38$]. At the end of day 1 the subjects had consumed 6.41, 6.57 and 6.74 MJ after the 1.66, 2.53 and 3.35 MJ preloads respectively [$F(2,64) = 0.25$, $p = 0.78$]. At the end of day 2 the subjects had consumed 16.66, 17.13 and 17.01 MJ after the 1.66, 2.53 and 3.35 MJ preloads respectively [$F(2,64) = 0.22$, $p = 0.80$].

The preload at 1500 hrs did not replace a normal meal and can be considered as an extra meal for that day. After the 1500 hrs croissants preloads no differences in energy intake were found at any of the periods of day 1 or day 2 between the three energy levels of the preloads [all $F(2,64) < 1.35$, $p's > 0.27$]. At the end of day 1 the subjects had consumed 5.59, 5.51 and 5.45 MJ after the

Table 4. The energy intake (MJ) on the study day (day 1) after preoad consumption, and the day after the study day (day 2) at six different periods of the day for the 9 different experimental conditions.*

	EXPERIMENTAL CONDITION								
	Preload at 0800 hrs			Preload at 1230 hrs			Preload at 1500 hrs		
	1.66 MJ	2.53 MJ	3.39 MJ	1.66 MJ	2.53 MJ	3.35 MJ	1.66 MJ	2.53 MJ	3.35 MJ
ENERGY INTAKE DAY 1:									
Breakfast	*PL*	*PL*	*PL*	*1.57*	*1.68*	*1.73*	*1.76*	*1.69*	*1.65*
During the morning	**[0.21]**	**[0.44]**	**[0.13]**	*0.36*	*0.50*	*0.38*	*0.31*	*0.45*	*0.41*
Lunch	**2.90**	**2.70**	**2.52**	*PL*	*PL*	*PL*	*2.48*	*2.43*	*2.40*
At 1500 hrs							*PL*	*PL*	*PL*
During the afternoon	**1.17**	**0.94**	**1.22**	**[1.22]**	**[1.22]**	**[1.28]**	**[0.24]**	**[0.19]**	**[0.28]**
Dinner	**3.81**	**3.98**	**3.64**	**3.94**	**3.99**	**3.87**	**4.21**	**3.86**	**3.97**
During the evening	**1.03**	**1.05**	**1.18**	**1.25**	**1.36**	**1.59**	**1.14**	**1.46**	**1.20**
ENERGY INTAKE DAY 2:									
Breakfast	**1.52**	**1.59**	**1.54**	**1.75**	**1.56**	**1.61**	**1.63**	**1.73**	**1.77**
During the morning	**0.84**	**0.63**	**0.32**	**0.49**	**0.54**	**0.66**	**0.44**	**0.52**	**0.55**
Lunch	**2.43**	**2.11**	**2.58**	**2.09**	**2.38**	**2.35**	**2.44**	**2.22**	**2.47**
During the afternoon	**1.34**	**1.07**	**0.78**	**0.97**	**0.93**	**0.96**	**1.22**	**1.32**	**0.87**
Dinner	**4.20**	**3.78**	**3.58**	**3.88**	**3.81**	**3.60**	**4.04**	**3.87**	**4.08**
During the evening	**1.26**	**1.47**	**1.89**	**1.07**	**1.34**	**1.14**	**1.46**	**1.37**	**1.17**

* Italic numbers indicate obligatory energy intake before the preload consumption. Bold numbers indicate energy intake after preload consumption. Bold numbers between brackets indicate that during part of this period subjects were not allowed to eat. PL: At this period the 2½ croissant preload was consumed. The preloads at 0800 and 1230 hrs replaced breakfast and lunch, the 1500 hrs preload was an extra meal for that day.

1.66, 2.53 and 3.35 MJ preloads respectively [F(2,64) = 0.04, p = 0.96]. At the end of day 2 the subjects had consumed 16.82, 16.54 and 16.36 MJ after the 1.66, 2.53 and 3.35 MJ croissants preloads respectively [F(2,64) = 0.14, p = 0.87].

Energy compensation

Energy compensation was calculated as the negative slope between the preload energy and the subsequent ad lib energy intake (Kissileff 1984). After the preload consumption the subjects showed no energy compensation for any of the three times of preload consumption at the end of day 1 between the three energy levels [all t32 < 1.01, all p's > 0.32]. Mean energy compensation values were 27% (sd = 152%), -20% (sd = 195%) and 8% (sd = 198%) after the preloads consumed at 0800 hrs, 1230 hrs and 1500 hrs respectively. At the end of day 2 (i.e. the energy intake after the preload consumption of day 1 plus the total energy intake of day 2) no statistically significant energy compensation was found [all t32 < 1.69, p's > 0.10] with mean values of 81% (sd = 277%), -22% (sd = 270%) and 28% (sd = 336%) for the 0800 hrs, 1230 hrs and 1500 hrs preloads respectively.

Macronutrient intake as a function of the energy level of the preload.

Table 5 shows the macronutrient intake after the preload consumption of day 1, and the total macronutrient intake of day 2, for each of the nine experimental conditions. On day 1, equal amounts (g) of fat, protein, carbohydrate and alcohol were consumed by the subjects after the three different energy levels in the 0800 hrs, the 1230 and 1500 hrs condition [all F(2,64) < 2.00, p's > 0.14].

When the macronutrient intake after preload consumption was regarded with respect to the percentage of energy derived by the different macronutrients, statistically significant differences in fat [F(2,64) = 3.37, p = 0.04] and carbohydrate intake [F(2,64) = 4.32, p = 0.02] were found between the three energy levels in the 0800 hrs condition, and no differences for the protein and alcohol intake. These differences did however not follow a dose response reaction. In the 1230 and 1500 hrs condition no differences in energy percentages were found between the three energy levels [all F(2,64) < 2.08, p's > 0.13].

On day 2 no differences were found in intake (g) of fat, protein, carbohydrate or alcohol, as a function of the nine experimental conditions of the former day [all F(8,256) < 1.05, p's > 0.40], nor for the percentage energy derived from the macronutrients [all F(8,256) < 1.24, p's > 0.28].

Table 5. The macronutrient (g) and energy (MJ) intake after preload consumption of day 1 and of day 2, for the 9 different experimental conditions.

	EXPERIMENTAL CONDITION								
	Preload at 0800 hrs			Preload at 1230 hrs			Preload at 1500 hrs		
	1.66 MJ	2.53 MJ	3.39 MJ	1.66 MJ	2.53 MJ	3.35 MJ	1.66 MJ	2.53 MJ	3.35 MJ
Intake DAY 1									
After preload	g (E%)	g (E%)	g (E%)	g (E%)	g (E%)	g (E%)	g (E%)	g (E%)	g (E%)
Fat	82 (33)	93 (38)	83 (36)	60 (35)	65 (36)	68 (37)	54 (36)	55 (36)	54 (36)
Protein	74 (14)	75 (14)	68 (14)	45 (12)	46 (12)	48 (13)	45 (14)	39 (13)	43 (14)
CHO	273 (50)	247 (46)	254 (49)	188 (50)	183 (48)	179 (46)	151 (46)	152 (47)	153 (48)
Alcohol	8 (2)	7 (2)	6 (2)	9 (4)	9 (4)	13 (5)	10 (4)	9 (5)	4 (2)
Energy (MJ)	9.13	9.11	8.68	6.41	6.57	6.75	5.59	5.51	5.44
Intake DAY 2									
Total	g (E%)	g (E%)	g (E%)	g (E%)	g (E%)	g (E%)	g (E%)	g (E%)	g (E%)
Fat	113 (35)	99 (34)	106 (37)	101 (37)	102 (36)	100 (36)	114 (37)	104 (35)	105 (36)
Protein	87 (13)	88 (14)	84 (13)	81 (14)	82 (14)	84 (14)	88 (13)	81 (13)	82 (13)
CHO	324 (48)	305 (50)	300 (48)	291 (48)	302 (48)	289 (48)	311 (48)	325 (50)	310 (48)
Alcohol	16 (3)	11 (2)	9 (2)	7 (2)	10 (2)	11 (3)	9 (2)	11 (3)	13 (3)
Energy (MJ)	11.59	10.64	10.69	10.24	10.55	10.32	11.23	11.03	10.90

E% = Percentage energy from the macronutrients.

When the macronutrient intake was regarded as percentage of the total energy intake of day 1 (pre-preload and preload intake values included) the percentages energy from fat were 46%, 40% and 34% with the 3.35, 2.53 and 1.66 MJ preloads respectively. The percentages energy from carbohydrates were 40%, 44% and 50% whereas the percentages energy from protein were 12%, 14% and 15% with the 3.35, 2.53 and 1.66 MJ preloads respectively.

Energy intake as a function of the time of preload consumption

The energy intake on day 2 did not show any systematic effects as a function of the experimental conditions of day 1. The mean energy intake of day 2, averaged over the nine conditions, was 10.80 MJ. When the total energy intakes of day 1 (i.e. with pre-preload and preload values) for each experimental condition were compared with this 10.80 MJ of day 2, systematic differences were found. The 3.35 MJ preload in the 0800 hrs condition resulted in higher total energy intakes on day 1 (12.37 MJ) compared with the mean intake of day 2 [$F(1,32) = 12.37$, $p = 0.001$]. The total energy intake with the 2.53 and 1.66 MJ preloads did not differ from the mean intake of day 2, with 11.64 and 10.79 MJ respectively [both $F(1,32) < 2.64$, $p's > 0.11$]. For the 1230 hrs conditions similar results were found with significant higher intakes with the 3.35 MJ preloads [$F(1,32) = 10.46$, $p = 0.003$] but with no differences for the 2.53 and 1.66 MJ preloads [both $F(1,32) < 4.05$, $p > 0.053$], with 12.25, 11.27 and 10.00 MJ respectively for the 3.35, 2.53 and 1.66 MJ conditions. For the 1500 hrs conditions all intakes on day 1 were higher than on day 2 with 13.29, 12.61 and 11.80 MJ for the 3.35, 2.53 and 1.66 MJ preloads respectively [all $F(1,32) > 8.41$, $p's < 0.007$].

Feelings of appetite for a meal

Figure 1 shows the absolute ratings for "appetite for a meal" over the entire day for the three different times of preload consumption averaged for the energy levels. It can be seen that the experimental manipulation, with the deprivation period of 210 minutes, has a strong influence on the "appetite for a meal" ratings. Equal values for "appetite for a meal" were found at times that were not directly influenced by the preload consumption or by the deprivation period.

Figure 2 shows the "appetite for a meal" ratings per time of preload consumption for the three energy levels. No statistically significant differences were found between the three energy levels for the 0800 and 1500 hrs experimental conditions. For the 12.30 hrs experimental condition one statistically significant difference was found after 30 minutes after the preload consumption [$F(2,64)=4.47$, $p=0.02$], whereas at the other time points no differences were found. A statistically significant interaction was found for the 1230 hrs condition between the time of the day and preload energy level [$F(16,512)=2.11$, $p=0.007$], which did not occur in the 0800 and 1500 hrs condition [both $F(16,512),1.24$, $p's>0.23$].

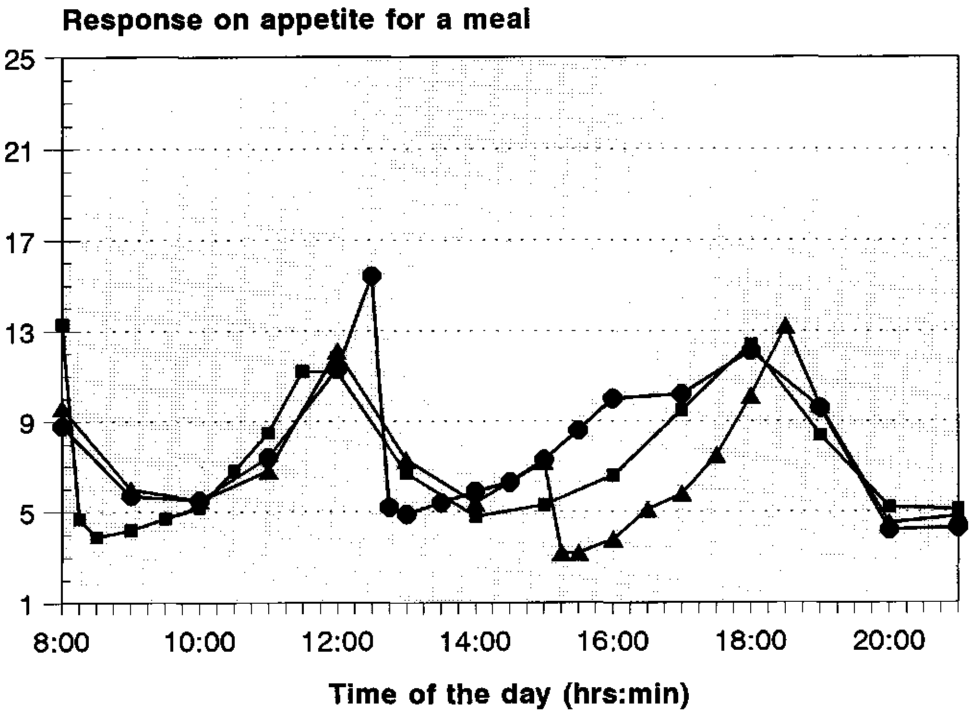

Figure 1. Absolute "Appetite for a meal" ratings from 1 (weak) to 25 (strong) on the study day from 0800 till 2100 hrs for the three different times of preload consumption, averaged over the three energy levels. □, preload at 0800 hrs; ○, preload at 1230 hrs; △, preload at 1500 hrs.

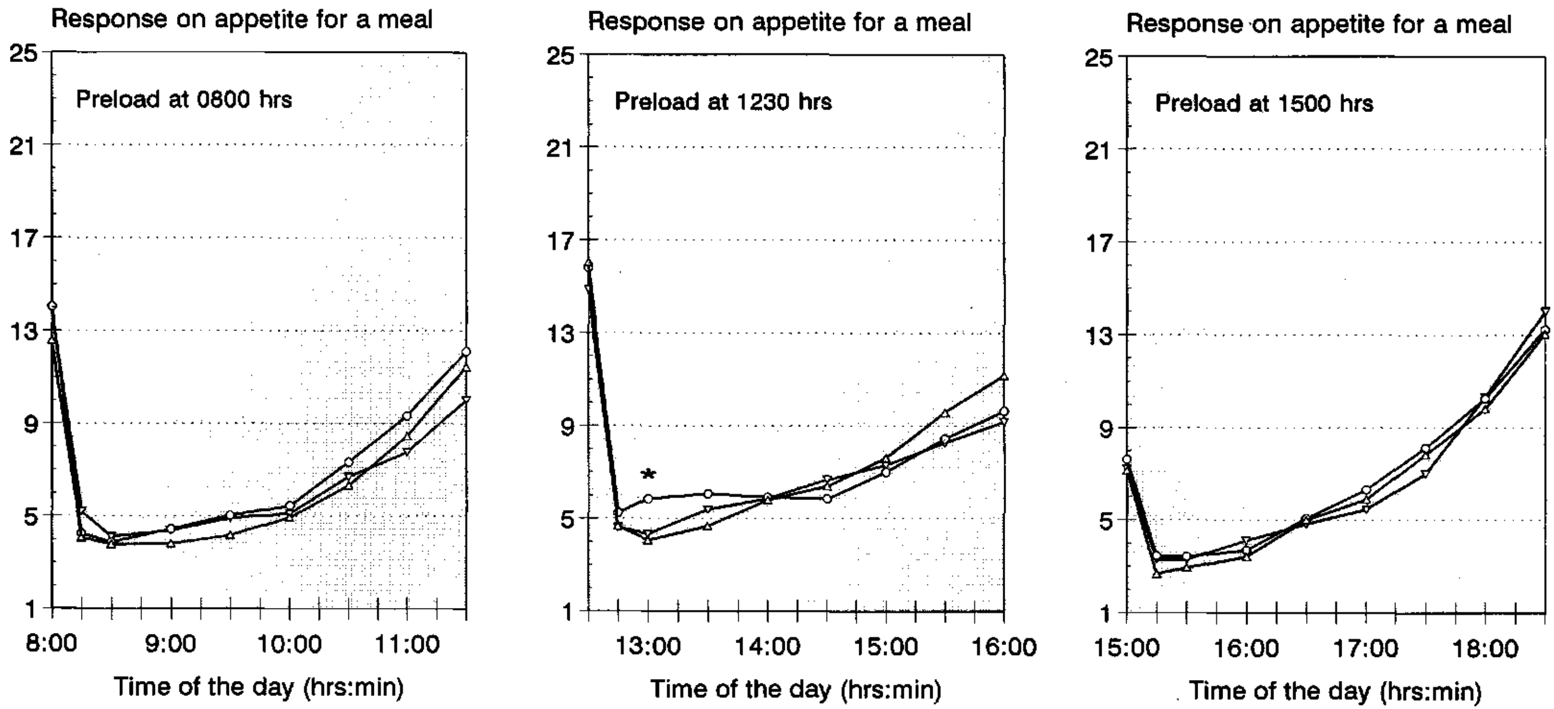

Figure 2. Absolute "appetite for a meal" ratings from 1 (weak) to 25 (strong) on the study day for the three energy levels (▿ = 1.66 MJ, ○ = 2.53 and ▵ = 3.35 MJ) per time of preload consumption. The "appetite for a meal" ratings are shown from just before preload intake till the end of the 3½ hour deprivation period. The left, middle and right chart show the ratings for the preloads consumed at 0800, 1230 and 1500 hrs respectively. An asterisk (*) indicates a statistically significant difference between the three energy levels at that time point.

To compare the effects of the three different times of preload consumption on appetite, analysis were performed when "appetite for a meal" ratings were parallelled, starting with the pre-preload consumption rating. There was a statistical significant difference between the absolute pre-preload values of the three times of preload consumption, $F(2,64)=35.93$, $p<0.001$, with the lowest value just before preload consumption at 1500 hrs. A statistical significant interaction was found between the time of preload consumption and the time after preload consumption, $F(16,512)=20.01$, $p<0.01$, indicating that the shape of the appetite curve was dependent of the time of the day of preload consumption.

DISCUSSION

The main finding of this experiment is that replacement of fat by sucrose poly-ester (SPE), or addition of fat in croissants did not result in significant compensation in energy intake, or altered feelings of hunger and satiety. The effects of the energy levels of the croissants on energy intake were the same for the different times of preload consumption.

The effect of energy level of the preload on energy and macronutrient intake.

The results on energy intake are in line with the long-term SPE-study of Glueck et al. (1982), and seem not to be in line with the short-term SPE-studies of Birch et al. (1993), Rolls et al. (1992) and Blundell et al. (1992), who reported complete energy compensation at the end of the study day.

In the latter two studies subjects received a lunch- and dinner-testmeal, separated by two deprivation periods of 3 and 4 hours respectively. After the dinner-testmeal subjects were free to eat ad libitum. In the present study a deprivation period of 3½ hours followed the preload consumption, after these 3½ hours the subjects were free to eat ad libitum. Rolls et al. (1992) and Blundell et al. (1992) investigated the substitution of 0 g (3.2 MJ), 20 g (2.4 MJ) and 36 g (1.9 MJ) fat by SPE. In the present study a substitution of 0 g (2.5 MJ) and 21 g (1.7 MJ) by SPE, and a 29 g fat addition (3.4 MJ) were investigated. When the energy compensation was calculated with the 0 and 20 g SPE conditions by Rolls et al. (1992) and Blundell et al. (1992), low values were found with 24% and 39% respectively. These values seem not to differ from the energy compensation values of the present study. The question arises whether the level of substitution or the absolute energy level is the factor that should be compared. If it is the level of substitution, then it is not necessary that the results are conflicting.

Birch et al. (1993) studied the effects of 14 g fat replacement by SPE in three meals from breakfast to lunch in children between 2 and 5 years old. She found 48% and 81% energy compensation at the end of day 1 and 2 respectively. It is not clear whether or not, and how, these results can be extrapolated to investigations with adult. Children from 2-5 years are probably no restrained eaters and are less influenced by cognitive factors than adults. It could be that children regulate their energy intake differently from adults (Birch et al. 1986).

In other short term studies that investigated the effect of different energy levels on subsequent energy intake inconsistent results were found. In two studies (De Graaf et al. 1992, Hulshof et al. 1993) with a similar design as the 0800 hrs preloads no sign of energy compensation was found. The studies Hill et al. (1987), Lawton et al. (1993), and Wardle (1987) are also in line with the present findings with no statistically significant energy compensation. In a study of Sepple and Read (1990) no significant energy compensation was found at lunch when a preload was consumed 20 minutes before the solid test meal at lunch. However, significant energy compensation was found (67%) when the preload was consumed 220 min before the lunch test meal. In a study of Rolls et al. (1990) significant energy compensation (98%) was found in a study where a preload was consumed 5 minutes before a lunch test-meal.

In the only long term study with SPE of Glueck et al. (1982) no energy compensation was found in 10 obese subjects, which is in line with the results from the present study where normal weight subjects participated. A difference was that in the study of Glueck et al. (1982) the manipulation took place over the entire day en not within a fixed preload. The present results are also in line with those of the long term studies of Lissner et al. (1987) and Kendall et al. (1991), where incomplete energy compensation was found; they reported average compensation values of 13% and 35% respectively.

In this study no energy or macronutrient compensation occurred. This means that a covert decrease in energy (fat) level of a food, results in a decreased total energy intake, in a short term design. After the preloads, the subjects consumed a diet with a similar macronutrient composition (energy percentage) in all nine experimental conditions, which had the same composition as on day 2. This could suggest that the subject consumed similar foods after the preloads similar to their normal diet. No macronutrient specific compensation is a result found often in recent studies (Geliebter 1979, Rolls et al. 1988, De Graaf et al. 1992, Hulshof et al. 1993). No macronutrient compensation indicates that the percentage energy derived from fat decreases when a fatreplacer is used, even if complete energy compensation were to occur. In the present study for the total energy intake of the study day, the percentage energy derived from fat decreased from 40% with the normal croissants to 34% with the SPE-croissants.

The effect of time of preload consumption on energy and macronutrient intake

When investigating the physiological effects of different products on food intake, only the food intake after the preload consumption is of interest. But when investigating the effects of different methodologies on food intake, both the food intake after, and the total food intake on the study day is interesting.

The time of the day at which the preloads were consumed did not influence the effects of the preloads on subsequent energy intake. Similar amounts of food were consumed after the three preloads for each time of preload consumption.

When the total energy intake of day 1 (i.e. with pre-preload and preload consumption) are compared between the conditions, the highest total intakes were found with the preloads at 1500 hrs, whereas the lowest total energy intake was found when the preload was consumed at 1230 hrs. The differences in energy intake can be explained by the differences between the energy content of the preload and the normal (usual) energy intake at the time of preload consumption. When the energy surplus of the preload compared to the normal intake increases, the total energy intake of the day will be higher. As no effects of the experimental manipulations on food intake on day 2 were found, day 2 was regarded as a reference day for the studied population. On day 2 the subjects from this study consumed the highest amount of energy at lunch with 2.34 MJ, followed by breakfast with 1.63 MJ, and during the afternoon with 1.04 MJ. These are about the numbers that were also found on the study day for the different periods (Table 4), suggesting that only minor differences in energy intake occurred at periods where the subjects were not directly influenced by the experimental manipulation.

For the macronutrient intake, similar results were found as for the energy intake, and no indication was found for a macronutrient specific compensation.

Feelings of hunger and satiety

The finding that the three energy levels of the preloads did not result in differences in feelings of hunger and satiety was also found in the SPE study of Rolls et al. (1992). In the study of Blundell et al. (1992) appetite was measured but not reported. In the longer term study of Glueck et al. (1982) no differences in appetite were reported, whereas in the study of Birch et al. (1993) no appetite ratings could be made as there were only children from 2 to 5 years old.

In the studies of De Graaf et al. 1992 (the fat manipulation), Wooley et al. 1972, Rolls et al. 1990 (Cheese on crackers) similar results as in the present study were found. Opposite results were found in the studies of Hulshof et al. 1993, Wardle 1987, Sepple and Read 1990, Rolls et al. 1990 (Tomato soup, and melon) where the different energy (fat) levels resulted in significant differences in appetite ratings.

Although significant differences were found with respect to sensory characteristics, we do not think that these differences have an independent effect on feelings of appetite. Hill et al. (1984) found an effect of lunches with different palatability on hunger after two hours, but not before. De Graaf et al. (1992) found no effects of differences in pleasantness on feelings of appetite and energy intake. Warwick et al. (1993) found differences in hunger and fullness ratings after preloads with different palatability, but no effects on the energy intake at the lunch test-meal. At the moment there is no clear evidence that palatability influences subsequent feelings of appetite or energy intake.

The appetite ratings were strongly dependent of the time of preload consumption. There was a strong interaction between the time of preload consumption and time. This interaction seems to originate from the normal pattern of appetite over the day, this is especially the case for the pre-preload values. When the post-preload values are regarded, the curves seem to act according to the next expected meal. In the 0800 and 1500 hrs conditions, a meal is expected within half an hour after the last rating, but in the 1230 hrs condition it will take at least two hours before dinner starts. In the latter case the appetite ratings did not rise firmly at the end of the deprivation period.

These differences in results between the different studies seem also to be due to differences other than the energy level. These could be differences in subjects, physical state of the food, or the methodology used (i.e. time of preload consumption, length of deprivation period, test-meals of ad lib food intake, fixed preload or ad lib preload consumption).

CONCLUSIONS

The replacement of fat by SPE or addition of fat in the preload croissants did not lead to changes in energy intake after consumption of these croissants. This was independent of the time of preload consumption. In this study fat had a weak satiating effect, which was also found by De Graaf et al. (1992) and Blundell et al. (1993). Just because fat has a weak satiating effect, SPE can help decreasing the fat and energy intake without resulting in complete fat or energy compensation, or affecting feelings of appetite.

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CHAPTER 5

SHORT-TERM EFFECTS OF HIGH-FAT AND LOW-FAT/HIGH-SPE CROISSANTS ON APPETITE AND ENERGY INTAKE, AT THREE DEPRIVATION PERIODS.

Toine Hulshof, Cees de Graaf, Jan A. Weststrate.

ABSTRACT

The short-term satiating effects of croissants with different amounts of fat and sucrose polyester (SPE) followed by three lengths of deprivation were investigated. Sixteen male and eighteen female normal-weight subjects each received six different experimental conditions in a two X three factorial design. Energy content was the first factor with two levels: 1.80 MJ and 3.45 MJ. The second factor was the deprivation period after the lunch preload with three levels: 0:15, 2:15, and 4:45 h. Subjects ate ad libitum after the deprivation period. The effects of the croissants were determined by motivational ratings and reported food consumption on the study day and the day after the study day. The SPE croissants (1.80 MJ) and the high-fat croissants (3.45 MJ) did not result in different subsequent energy intakes. Differences in energy intake were found between the three deprivation conditions, with the lowest intake with the 4:45 h deprivation condition. This was due to differences in the energy intake during the afternoon. The two energy levels of the preloads had similar effects on the motivational ratings. Higher appetite ratings were found after the 4:45 h compared to the 0:15 h and the 2:15 h deprivation condition.

INTRODUCTION

In the Netherlands, as in other developed countries, the average total fat intake is too high (13). An overconsumption of fat or energy is related to many diseases like obesity, NIDDM, heart disease, and cancer (24). Compared to the 37% energy from fat, which was consumed in the Netherlands in 1991/1992 (19), the recommended fat intake is between 30% and 35% (28). Therefore efforts have to be made to reduce the dietary fat intake.

Fat replacers like sucrose polyester (SPE) can be used to reduce the fat and energy content of food products. SPE is a fat replacer that does not provide energy to the human body. It is made from chemically linking of sucrose molecules with fatty acids, derived from edible oils or fats. SPE has a similar appearance and the same physical and sensory properties as normal dietary fat, but it is not digested and absorbed in the human body (11). One of the main question with respect to the use of fatreplacers in food is whether or not the replacement results in fat or energy compensation. SPE would only be a useful tool to decrease fat or energy intake, if energy or fat compensation is less than complete.

Six studies about the satiating efficiency of SPE have been published (2,4,8,12,14,23). In the short term studies of Rolls et al. (23), Blundell et al. (4) and Birch et al. (2) complete energy compensation was reported. In the short-term studies of Hulshof et al. (14), and Cotton et al. (8) no significant energy compensation was found, like in the only longer-term study of Glueck et al. (12).

The preloading paradigm seems to be the best methodology, with either a preload-testmeal design or a preload-ad libitum food intake design, to investigate the short term satiating effects of food products (17). Both designs involve a period during which the subjects are not allowed to eat or drink. During this deprivation period the temporal tracking on feelings of hunger and satiety can be investigated without interferences of food intake. In the case of a short deprivation period (less than 30 min) mainly the sensory and cognitive effects on satiety will be measured. When the deprivation period is longer (i.e. 240 min.), postingestive (but preabsorptive) and postabsorptive effects are also included (5). This issue is particular relevant when studying the differences between fat and SPE, where no differences can be expected by the sensory and cognitive factors, but only during the postingestive (but preabsorptive) and postabsorptive phase.

When a preload-test meal design is given to the subjects, more accurate energy intake data can be obtained compared to a preload-ad libitum intake design. However, in the latter case less deviation from the normal eating behaviour will be created compared to a preload-test meal study, and the external validity will be higher. Depending on the research question one can choose either methodology.

In the literature the length of the deprivation period after preload consumption varied from no deprivation (3) to 300 min deprivation (29). Often no reason for the choice of the length of the deprivation period is given. When a short deprivation period is used, the emphasis will be on the effects of preloads on energy intake. When the deprivation period is longer, often the emphasis of the study is on both the appetite feelings and energy intake.

To date, seven studies have been performed in which the effects of different deprivation periods on the satiating efficiency of foods was investigated (3,6,7,21,22,25) with different methodologies and controversial data.

The main objective of the present study was to investigate whether the differences in fat and energy content of a high-energy (3.45 MJ) and a low-energy (1.80 MJ) preload, by substituting fat by SPE, resulted in differences in subsequent food intake and feelings of hunger and satiety. This study was performed with three different postpreload deprivation periods (0:15, 2:15, 4:45 h). The present study is the first study in which the effect of different deprivation periods on ad libitum food intake on the study day and the day after the study day is investigated.

Table 1. Main characteristics of the subjects

	Men (n = 16)		Women (n = 18)	
	Mean	(sd)	Mean	(sd)
Age (years)	22	(3)	22	(1)
Height (cm)	183	(7)	173	(8)
Weight (kg)	72	(6)	63	(7)
BMI (kg/m^2)	21	(1)	21	(2)
Fat percentage (%)*	16	(4)	26	(5)
Restrained eating score†	1.6	(0.4)	2.5	(0.6)

* Calculated with the biceps + triceps skinfolds and the formula of Durnin and Womersley (1974).

† The restrained eating score was measured with the DEBQ of Van Strien (1986). The minimum value is 1 (no restraint) and the maximum value is 5 (high restraint).

METHODS AND MATERIALS

Subjects

Seventeen male and 16 female volunteers, between 19 and 25 years old, participated in the study. Subjects with a BMI larger than 25 kg/m^2 or a restraint score over the 80th percentile (> 2.37 for men, > 3.24 for women) on the Dutch Eating Behaviour Questionnaire of Van Strien et al. (27) were excluded for participation. All subjects were student at the Wageningen Agricultural University and were paid for participation. Every subject signed an informed consent before participation in the study. The subjects were told that the experiment was meant to investigate the effect of meals on feelings of hunger and satiety, and that there was a possibility that SPE was used in the preloads. Post experimental briefing revealed that the subjects were not aware of the substances used in the different preloads. The experiment was approved by the Medical Ethical Committee of the Department of Human Nutrition. Table 1 shows the main characteristics of the subjects of this study.

Experimental conditions

There were six experimental conditions, composed according to a three X two factorial design. The energy content of the preloads was the first factor with two levels: 1.80 MJ (430 kcal) and 3.45 MJ (825 kcal). The length of the postpreload interval was the second factor with three levels: 0:15, 2:15 and 4:45 h. The length of the deprivation periods and the time of preload consumption were chosen so the normal meal pattern of the subject would not be influenced. In the 0:15 h deprivation period subjects could almost immediately start eating after the preload. The 2:15 h deprivation period was chosen because in a study of De Graaf et al. (9) it was found that after preloads of 0.42, 1.05 and 1.67 MJ the largest differences in appetite occurred between 2:00 and 2:30 h after the preload consumption. The 4:45 h deprivation period was chosen as the longest possible deprivation period without influencing the subject's normal meal pattern. Before the study started, a test day was run to let the subjects get acquainted with the procedures of the study. Every preload was consumed at lunchtime, and consisted of two and a half croissants spread with (low-fat) margarine, and with ham or (low-fat) cheese. The total weight of the preloads was approximately 177 gram. The energy content of the croissants was predominantly manipulated by varying the fat content, by adding extra fat or by replacing fat with SPE. In the low-fat croissants

24-g SPE was used, instead of the 24-g margarine like in normal croissants. In the high-fat croissants 34-g margarine was used. The croissants were baked in the bakery of Unilever Research Laboratorium Vlaardingen (The Netherlands), and kept frozen until the day of consumption. The spread, ham, and cheese were commercially available products, bought in a local supermarket. Table 2 shows the energy and macronutrient composition of the two different preloads.

Table 2. Energy and macronutrient composition of the two and a half corissants spread with ham and cheese, that were served as lunch.

Preload	Weight	Energy		Macronutrients			
				FAT	Protein	CHO	SPE
	g	MJ	(kcal)	g (E%)	g (E%)	g (E%)	g (E%)
Low fat	177	1.80	(430)	13 (28)	24 (22)	54 (51)	24 (0)
High fat	178	3.45	(825)	64 (70)	19 (9)	42 (21)	0 (0)

E% = Percentage energy derived from the specific macronutrient.

Measurements

Eating behaviour characteristics of the subjects.

Before the experiment started, all subjects completed the Dutch Eating Behaviour Questionnaire (DEBQ) developed by van Strien et al. (27), producing scores for restrained eating, external eating, and emotional eating.

Subjective feelings of hunger and satiety

Subjective feelings of hunger and satiety were rated by means of a slash on five 150-mm visual analogue scales as described by Hulshof et al. (15). In this study only the ratings of "appetite for a meal" are presented, as a former study revealed that this item was the best to describe general hunger (9). The term "appetite for a meal" was placed above the centre of the visual analogue scale, which was anchored on the left- and right-hand side with the terms weak and strong, respectively. Written and oral instructions were provided to inform the subjects about the meaning of the terms. "Appetite for a meal" referred to appetite for a complete meal, either a hot meal or a sandwich meal.

Energy and nutrient intake

Energy and nutrient intake were recorded by means of a food diary. All the foods and drinks consumed during the evening meal were weighed to an accuracy of 2 g on electronic scales (Soehnle scalina, Soehnle-Waagen GMBH & Co, Murrhardt/Württ, Germany). The weight of the other foods consumed during the day were estimated by means of standards for household measures. In the normal Dutch diet, lunch and snack items usually consist of standard food items, of which the weight can be accurately estimated by standard household measures. This is not the case for the foods and drinks at the evening meal. The food diaries were checked and coded by experienced dieticians. In case of unclear food records subjects were asked about them by the dietitians within a week. Energy and nutrient intake were calculated using the Dutch food composition table (20).

Table 3. The visual attractiveness, pleasantness,and sensory attributes (on 150 mm visual analogue rating scales) for the two different preloads averaged for the ham and cheese croissant.

Attribute	**Energy level of the preload**	
	1.80 MJ mm	3.45 MJ mm
Visual attractiveness	77	93 **
Sweetness	43	44
Sourness	30	33
Saltiness	61	69 *
Bitterness	16	17
Creaminess	54	79 **
Crispness	37	51 **
Greasiness	57	92 **
Dryness	82	46 **
Pleasantness	70	84 *

* $p<0.01$; ** $p<0.001$

Sensory perception and pleasantness

Subjects rated the pleasantness and the perceived intensity of both the ham and cheese croissant within each preload according to 19 attributes on 150-mm visual analogue scales. Visual attractiveness of the croissant was rated before preload consumption. The remaining attributes were rated during the consumption of the croissants. The main attributes were: sweetness, saltiness, sourness, bitterness, greasiness, crispness, and croissant-taste. Table 3 shows the mean response averaged for the attributes for the two preloads, averaged for the ham and cheese croissant values per preload.

Procedure

The six different experimental conditions were offered in a random sequence that varied for each subject. Every subject received each preload on a different day, resulting in a within-subjects repeated-measures design. One test day was run before the first study day, to familiarize the subjects with all the procedures of the experiment. Study days were always on Tuesdays and Thursdays to eliminate weekend effects. The whole study lasted for 4 weeks.

Subjects were invited to come to the department at 12:30 h, where the preloads were presented to the subjects. The croissants with ham and cheese were served on a plate together with one glass of water (200 ml) as a drink. The croissants and the water were consumed within 15 min. Every study day the subjects were told which croissant (ham or cheese) they had to consume first according to a random scheme. After preload consumption, subjects opened an envelop with a note at what time they were allowed to eat again (either 13:00, 15:00, or 17:30 h). In this way subjects could not be influenced by the knowledge of the length of the deprivation period with respect to the feelings of appetite and the consumption of the preloads.

The subjects were asked not to eat or drink anything, except water, after 23:00 h the previous evening, and to live a regular life style without excessive events. On the morning of the study days subjects consumed a standard morning eating pattern. This standardised morning eating pattern was written down by the subject and discussed with a dietitian before the study started. A copy was returned to the subject. Subjects were requested to consume the standard morning eating pattern every study day. Deviations in the standard morning eating pattern were reported to the dietitians, who recalculated the food intake for that morning.

Subjects were instructed to rate their subjective feelings for "appetite for a meal" every clock hour of the study day from 09:00 till 22:00 h. Additional ratings were made just before (12:30 h) and just after (12:45 h) the consumption of the preload. When the deprivation period was 4:45 h long an additional rating was made at 17:30 h. Sensory perception and pleasantness of the preload were rated just before and during the consumption of the preload. During the deprivation period subjects were not allowed to eat or drink except water. After the deprivation period subjects were instructed to eat and drink whatever they wanted. For the remainder of the study day (day 1) and the day after the study day (day 2) subjects recorded all the food and drinks in the food diary.

Data analysis

Ratings on "appetite for a meal" were read by an Optical Mark Reader and converted into scores from 1 (weak) to 25 (strong). To enable one overall comparison of the effects of the two different preloads on appetite ratings, the area under the curve as a percentage of the maximum area (AUC%) was taken as the dependent variable (instead of the seven appetite ratings). An advantage of the area under the curve is that is gives one value, and the effects of the preloads can be compared directly with each other (instead of comparing curves). Another advantage is that this measure takes into account the magnitude of the different time intervals between the adjacent measurements (which is not the case in ANOVA over the time interval). The disadvantage of this analysis is that the temporal tracking of the appetite feelings is missed (15).

The area under the curve was calculated as percentage of the total area by the following equation:

$$(((1/8\ (A+2B+5C+8D+8E+8F+4G))-4\tfrac{1}{2})/108)*100,$$

where A, B, C, D, E, F, G, are the appetite ratings at 0, 15, 30, 90, 150, 210 and 270 minutes respectively. The lower the area under the curve for "appetite for a meal" the more satiating the preload is.

Energy compensation was calculated as the difference in energy intake on the study day between the low-energy preload and the high-energy preload divided by the difference in energy between the preloads (1.65 MJ).

ANOVA for repeated measures of the SAS statistical software package (26) was used to analyze the effects of the six experimental condition, the energy levels of the two preloads, and the length of the deprivation period on absolute appetite ratings, AUC% values, energy and macronutrient intake. The type of preload was the fixed within-subject factor, and subjects were the random factor.

RESULTS

Energy and macronutrient intake as a function of the energy level of the preloads.

The total energy and macronutrient intake of day 1 (preload values excluded) are shown in Table 4. The energy intake on day 1 **(preload values excluded)** with the low-fat/high-SPE preload was higher (on average 0.36 MJ) compared with the high-fat preload. This was found for every deprivation condition, but did not reach statistical significance [$F(1,33) = 1.66$, $p = 0.21$]. The mean energy compensation averaged over the 34 subjects was 22% with a standard deviation of 156%. No significant differences in protein, fat, carbohydrate and alcohol intake were found between the two energy levels of the preloads [all $F's(1,33) < 1.49$, $p's > 0.23$], indicating that no macronutrient specific compensation did occur.

Table 5 shows the energy intake for six time periods of the day for the two different energy levels of the preloads. No statistically significant difference in energy intake was found between the two energy levels of the preloads for any of the time periods [all $F's(1,33) < 2.33$, $p's > 0.14$].

When the total energy and macronutrient intake of day 1 was regarded **(preload values included)** significant differences were found for fat [$F(1,33) = 153.1$, $p < 0.0001$], carbohydrate [$F(1,33) = 5.84$, $p = 0.02$] and energy intake [$F(1,33) = 24.05$, < 0.0001], but not for protein and alcohol [both $F's(1,33) < 1.81$, $p's > 0.19$]. The differences were primary due to the differences in the preloads that were given.

The energy or macronutrient intake of the day after the study day (day 2) was not influenced by the two energy levels of the preloads of day 1 [all $F's(1,33) < 2.02$, $p's > 0.16$].

Energy and macronutrient intake as a function of the length of deprivation period.

For both the low-fat/high-SPE and the high-fat preload energy intake was decreased with the 4:45 h compared to the other two deprivation periods, [$F(2,66) = 2.70$, $p = 0.07$]. There were no effects of deprivation time on macronutrient intake [all $F's(2,66) < 2.20$, $p's > 0.12$].

To obtain more information about the effects of the different experimental conditions on energy intake, energy intakes are given in Table 5 for six different time periods of the day. During the afternoon of the study day a significant

Table 4. The energy (MJ) and macronutrient intake (g) on the study day (day 1) without preload values and the day after the study day (day 2) for the six different experimental conditions. The 34 subjects received 2½ croissants with different amounts of fat and SPE as lunch.

	EXPERIMENTAL CONDITION					
	0:15 h deprivation		2:15 h deprivation		4:45 h deprivation	
	1.80 MJ	3.45 MJ	1.80 MJ	3.45 MJ	1.80 MJ	3.45 MJ
Total Intake DAY 1*						
Fat intake (g)	82	86	84	76	79	70
CHO intake (g)	297	250	255	266	249	236
Protein intake (g)	74	75	72	75	71	69
Alcohol Intake (g)	9	7	9	6	8	8
	-----	-----	-----	-----	-----	-----
Energy intake (MJ)	9.24	8.86	8.90	8.76	8.54	7.98
Total Intake DAY 2						
Fat intake (g)	99	112	112	104	111	101
CHO intake (g)	329	327	310	303	318	318
Protein intake (g)	88	96	84	86	90	83
Alcohol Intake (g)	15	9	14	9	12	12
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Energy intake (MJ)	11.11	11.55	11.22	10.73	11.37	10.89

* Note that the energy intake of day 1 is without the energy of the preload.

Table 5. Energ intake (MJ) at six different periods of the study day for the three different deprivation periods and for the two energy levels. The 34 subject received 2½ croissants with different amounts of fat and SPE as lunch.*

	EXPERIMENTAL CONDITION				
	Deprivation period (h:min)			Energy level of preload	
	0:15	2:15	4:45	1.80 MJ	3.45 MJ
Breakfast	*2.00*	*1.94*	*2.01*	*2.01*	*1.96*
During the morning	*0.45*	*0.43*	*0.47*	*0.46*	*0.43*
Lunch (preload)	*2.63*	*2.63*	*2.63*	*1.80*	*3.45*
During the afternoon	**1.16**	**1.09**	**0.58** **	**1.04**	**0.84**
Dinner	**3.96**	**4.02**	**3.69**	**4.00**	**3.78**
During the evening	**1.49**	**1.35**	**1.51**	**1.38**	**1.52**
Total intake day 1	11.69	11.86	10.89	10.69	11.98

* Italic numbers indicate obligatory energy intake, whereas bold numbers indicate energy intake values after preload consumption.

** $p < 0.01$.

decrease in energy intake (on average 0.55 MJ) was found for 4:45 h compared to the 0:15 and the 2:15 h deprivation period [$F(2,66)=6.48$, $p=0.002$]. The differences in deprivation period did not result in significant differences in energy intake at dinner or during the evening. The differences in energy intake between the three deprivation periods during the afternoon were due to decreases in protein, fat and carbohydrate intake, but with a major contribution carbohydrate intake which decreased from an average of 37 g in the 0:15 and the 2:15 condition to 17 g in the 4:45 condition [$F(2,66)=10.31$, $p<0.0001$].

The energy or macronutrient intake of the day after the study day (day 2) was not influenced by the three different lengths of the deprivation periods of day 1 [all $F's(2,66)<2.25$, $p's>0.11$].

Feelings of appetite for a meal.

Figure 1 shows the values for the area under the curve in percent of the maximum area (AUC%) for "appetite for a meal" for the six different experimental conditions. There was a significant difference in AUC% between the six conditions [$F(5,165)=3.35$, $p=0.0045$]. This difference was due to the different deprivation periods [$F(2,66)=6.28$, $p=0.0032$], and not because of the energy differences of the preloads [$F(1,33)=2.57$, $p=0.12$].

The differences in AUC% between the two energy levels for each deprivation period showed no differences for the 0:15 and 2:15 h deprivation periods [both $F's(1,33)<0.55$, $p's>0.46$]. However for the 4:45 h deprivation period a 5% lower AUC for "appetite for a meal" was found with the 3.45 MJ preload in both men and women, but this was not statistically significant [$F(1,33)=2.72$, $p=0.11$].

It should be noted that only in the 4:45 h deprivation condition, the AUC% is not influenced by food intake. In the 0:15 and 2:15 h deprivation condition the appetite ratings could be influenced by food intake within the period of 4:45 h after preload consumption.

Figure 2 shows the curves of the absolute values for "appetite for a meal" for the three different deprivation periods, averaged over the energy levels. The 0:15 and 2:15 h deprivation period resulted in similar "appetite for a meal" values over the entire period of 4:30 h, with the largest difference after 4:30 h [$F(1,33)=1.53$, $p=0.23$]. This indicates that a deprivation period of 2:15 h does not influence the normal eating pattern.

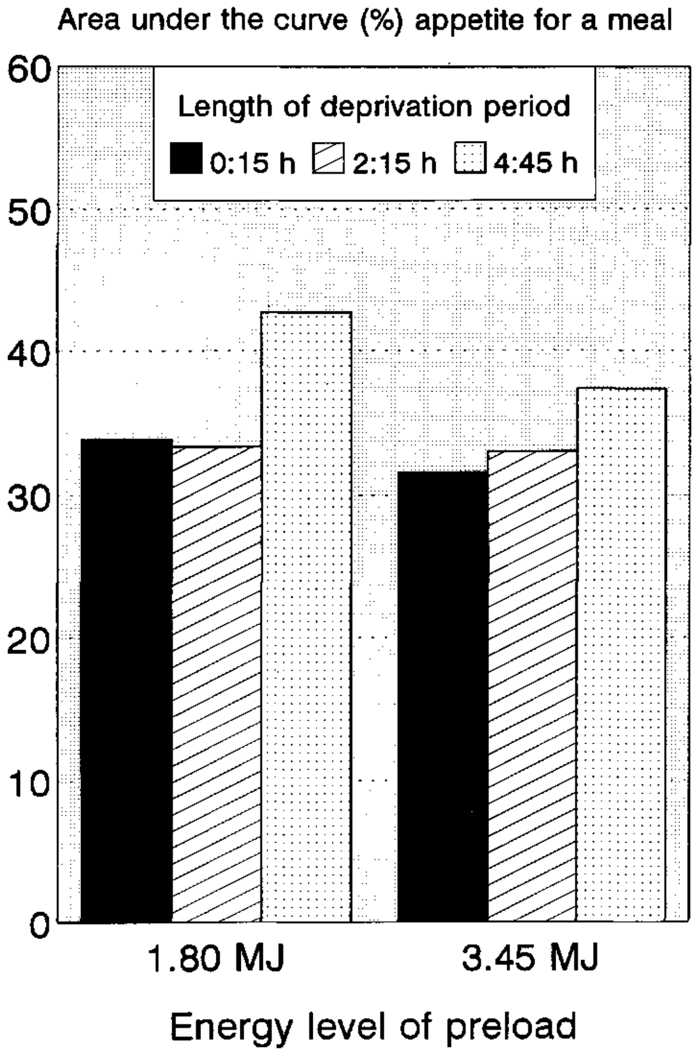

Figure 1. Mean area under the curve as percentage of the total area (AUC%) for "appetite for a meal" for the six experimental conditions after preloads of 2½ croissants at lunch time. The AUC% was calculated for the period of 4:30 h after the rating just before the preload consumption. Note that for the 0:15 and the 2:15 h deprivation period the appetite rating could be influenced by food intake.

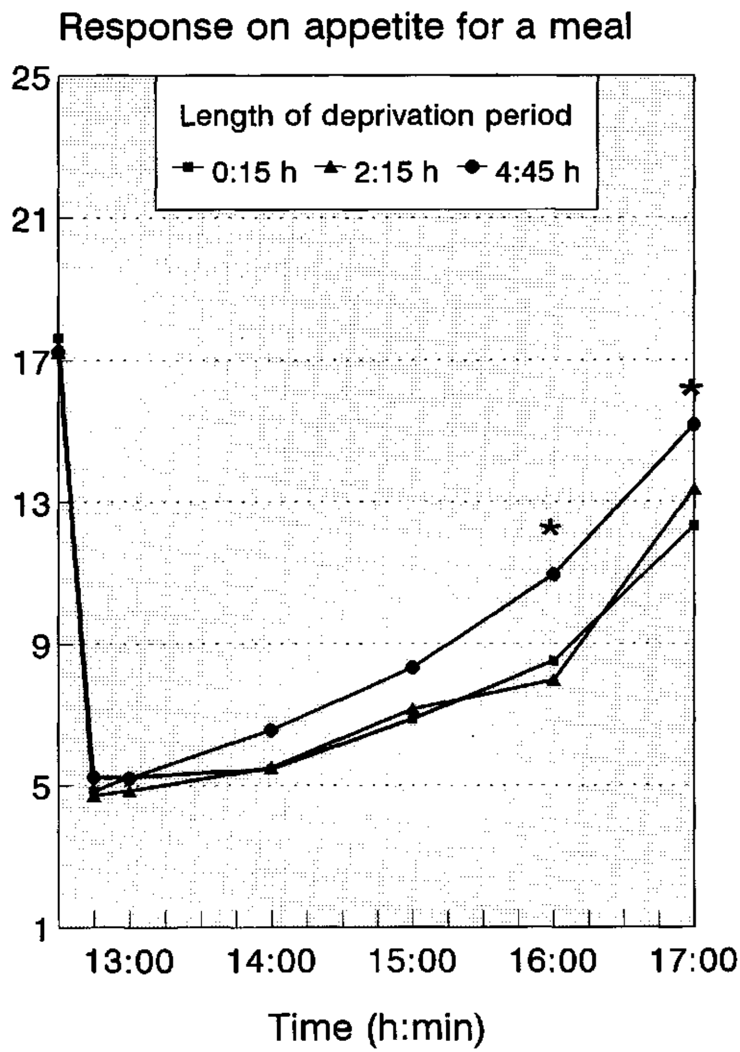

Figure 2. Absolute "appetite for a meal" ratings on the study day for the three different deprivation periods conditions. The first rating is taken just before preload consumption at 1230 h. * = statistically significant difference between the three deprivation conditions ($p<0.05$, $F(2,66)$).

When the "appetite for a meal" values were regarded per sex it was found that men rated higher AUC% values (45%) then women (27%). However, the patterns in AUC% values for the six experimental conditions were similar for men and women, with more "appetite for a meal" after the 4:45 h compared to the 0:15 and the 2:15 h deprivation period.

DISCUSSION AND CONCLUSIONS

The main finding from this study is that a 1.7 MJ difference in energy level of croissant preloads resulted in similar amounts of energy intake on the study day (without the energy of the preload) and similar feelings of appetite. These results were not influenced by the length of the deprivation period. The length of the deprivation period did influence the amounts of food intake and appetite ratings, with less energy intake and more "appetite for a meal" after the 4:45 h compared with the 0:15 and the 2:15 h deprivation period.

Energy intake as a function of the energy level of the preload.

In the present study 22% (n.s.) of the energy difference was compensated for, which is in line with other short term studies on SPE by us (14,16), and the longer-term study of Glueck et al. (12). The result were not in line with the three other short-term studies performed with SPE as a fat-replacer (2,4,23). In those studies almost complete energy compensation was reported. In the study of Birch et al. (2) 2-5 year-old children compensated almost completely for the energy deficit. Birch et al. (1) also found that children were more likely to compensate for covert energy differences than adults. The differences in the present study with the studies of Blundell et al. (4) and Rolls et al. (23) could be due to differences in the methodology. They gave the subjects a breakfast preload followed by deprivation periods and test meals at 12:00 and 16:00 h. In this way the normal meal pattern was changed, as dinner is normally a few hours later. It could be that this influenced the food intake of the subjects during the evening.

Post experimental briefing revealed that the subjects were not aware of the differences in energy level between the preloads, although the sensory measurements showed significant differences between the preloads. We think that these differences did not influence the amounts eaten after the preload, as the sensory differences between both preloads were not large.

It should be mentioned that in almost all studies on the satiating efficiency of products, the subjects are unaware of the differences, whereas in normal life the subjects almost always know what they are eating. Therefore it is difficult to extrapolate the outcomes of these studies to normal life situations (30).

Energy intake as a function of the length of deprivation period.

In the present study it was found that with the 4:45 h deprivation period energy intake was 0.6 and 0.5 MJ lower when compared with the 0:15 and 2:15 h deprivation period, respectively. This difference in energy intake was mainly due to differences in energy intake during the afternoon. In the 4:45 h deprivation period condition subjects were deprived till 17:30 h, whereas in the 0:15 and 2:15 h deprivation condition they were not allowed to eat till 13:00 and 15:00 h.
The time between 17:30 h and dinner was to short to catch up for the missed foods they normally ate during the afternoon. It could be that in the 4:45 h condition the subjects consumed some food (e.g. 0.58 MJ) just before dinner time because of hunger due to the 4:45 h deprivation.

The six different experimental conditions did not result in any effect on energy intake on day 2 (the day after the study day). This was also found in two studies of Hulshof et al. (14,15), and Lawton et al. (18). It could be that during the night when the subjects sleep, appetite feelings are reset in a way that the given manipulations do not result in statistically significant differences in food intake the day after.

Effects on macronutrients

There were no differences in macronutrient intake after the two preloads or the three deprivation periods. When the fat in the croissant was replaced by SPE, no extra fat was consumed as compensation. This indicated that there is no macronutrient specific compensation.

Feelings of appetite for a meal as a function of the preloads

No differences in "appetite for a meal" ratings were found between the low-fat/high SPE and the high-fat preload. This is in line with the studies of Blundell et al. (4), Hulshof et al. (14) and Rolls et al. (23), but not with two other studies of us where artificial preloads were given (9,15). It could be that differences between artificial products and normal food products produced the difference in outcome, or the difference between liquid versus solid preloads (15).

Women rated lower values for "appetite for a meal" after the preloads although the prepreload values did not differ between the sexes. As the preload had equal size and energy content for men and women, it was found that the appetite feelings were more depressed in the group with the lighter subjects (women), as was found in two other studies of Hulshof et al. (14,16). Similar patterns in energy intake and for feelings of appetite were found in both men and women.

Feelings of appetite for a meal as a function of the length of the deprivation period.

The different deprivation times resulted in different ratings for "appetite for a meal", with the highest ratings after the 4:45 h deprivation period. This is probably due to the fact that in the 0:15 and 2:15 h condition subjects were allowed to eat after 0:15 and 2:15 h respectively. In these two situations, the subjects probably ate before the 4:45 h period was over. These eating moments would have a suppressive effect on "appetite for a meal". It should be noted that the "appetite for a meal" values for the 0:15 and 2:15 h periods are therefore directly influences by the food intake of the subjects. No differences in "appetite for a meal" were found between the 0:15 and the 2:15 h deprivation period indicating that normally subjects do not eat within 2:15 h after lunch.

In a study of Hulshof et al. (14), where similar croissant preloads were used as in the present study, the effects on appetite and energy intake with a preload consumption at lunchtime followed by a deprivation period of 3:15 h were investigated. Although different subjects participated in that study, similar results were found for appetite (25 AUC% for the 1.66 MJ and 24 AUC% for the 3.39 MJ preload) and energy intake (30% energy compensation (n.s.)).

CONCLUSIONS

The subjects in this study did not compensate for the energy deficit obtained by replacing fat with SPE. For the short term, covert SPE use can decrease energy and fat intake.

If a preload-test meal or a preload-ad libitum food intake study is run, then the length of the deprivation period can influence the appetite feelings and the energy intake. During the periods where the normal meal/snack pattern is changed by the methodology used, differences in energy intake will be found.

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CHAPTER 6

SHORT-TERM SATIATING EFFECT OF THE FATREPLACER SUCROSE POLYESTER (SPE) IN MAN.

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ABSTRACT

The effects of different amounts of the non absorbable fat replacer, sucrose polyester (SPE), water, and fat added to six warm preload lunches on feelings of appetite and food intake were investigated in two studies that were replicates of each other. In the first study 39 subjects consumed rice preloads, in the second study 35 subjects consumed macaroni preloads. The six preloads were fixed on three energy levels: 1.8 MJ, 2.7 MJ, or 3.7 MJ. Two hours after preload consumption a test-meal buffet of 31 products was presented. Food intake was recorded on the study day, and the day after the study day. For women no energy compensation occurred in either study. Men showed a tendency to compensate for the energy differences between the preloads. However, when the fat of the preloads was replaced by SPE, energy compensation was less than 50% and non-significant. Statistically significant energy compensation was found (66%) when fat was substituted by water. No macronutrient specific compensation occurred in men or women in either study. Lower total fat- and energy-intakes were found with the preloads where fat was replaced by SPE compared to the preloads with fat. The appetite ratings were in line with the energy intake values, with no differences in women, and higher appetite ratings after the lower energy preloads in men. This short term study indicates that SPE may be a useful aid to reduce fat- and energy-intake.

INTRODUCTION

Sucrose Poly-ester (SPE) is a non-caloric fat replacer made from chemically linking of sucrose molecules with fatty acids, derived from edible oils or fats. SPE has a similar appearance, and the same physical and sensory properties as normal dietary fats, but it is not digested and absorbed in the human body (Fallat *et al.* 1976). SPE could be a useful substance to reduce the fat and the energy content of food products. One of the major nutritional issues with respect to the replacement of fat by SPE, is the question whether or not this replacement results in a behavioral adaptive response regarding food intake. SPE will only contribute to a reduced fat or energy intake when subjects do not compensate for the energy or fat deficit, when fat is replaced by SPE.

Up till now only five short term studies (Blundell *et al.* 1992; Rolls *et al.* 1992; Hulshof *et al.* 1993; Hulshof *et al.* 1993; Cotton *et al.* 1993) and one longer term (Glueck *et al.* 1982) study have been performed on the effect of SPE on feelings of hunger and satiety and subsequent food intake. Blundell et al. (1992) and Rolls et al. (1992) found complete energy compensation for the energy deficit sustained at breakfast. However no compensation was found in the lunch test-meal in both studies. The compensation occurred in both studies at the second test meal (7 hours after breakfast) and afterwards in the evening. In the study of Rolls et al. (1992) no consistent differences in appetite ratings were found at any time of the day between the SPE and fat preloads. In two studies of Hulshof et al. (1993a, 1993b) the satiating effect of croissants with either fat or SPE was investigated. The energy difference of 1.65 MJ between the SPE- and fat-preload, did not result in differences in subsequent energy intake on the study day nor on the day after the study day for both studies. Feelings of hunger and satiety were not influenced by the replacement of fat by SPE. Cotton et al. (1993) investigated the effect of replacing 55 g fat (2.0 MJ) by SPE in two studies. No energy compensation in either study was found indicating that SPE is as satiating as fat. In the only longer term study with SPE of Glueck et al. (1982) in obese subjects no energy compensation and no differences in appetite feelings were found.

In conclusion, there is no consensus about the effect of the replacement of fat by SPE on subsequent energy intake. Several factors may be responsible for these discrepancies, with as main reason the differences in methodology used. To obtain more robust results, we decided to perform two studies that were replicates of each other, with relatively large numbers of subjects, both men and women, and with a sensitive design (preload test-meal design).

In the present study the main goal was to investigate the effects of different doses of fat and SPE on feelings of hunger and satiety and subsequent energy intake. This paper deals with two studies, the second study (with macaroni meals) being a replicate of the first study (with rice meals). As large differences in results between men and women were found, the effects of the fat and SPE manipulation for both men and women are presented as well.

SUBJECTS AND METHODS

In this paper two similar studies with a preload test-meal design are presented. As studies on appetite are difficult to replicate between research centres, we felt it necessary to confirm the results of the first study by replicating it within the same research group. This replication would increase the generalizability of the results. The second study was a replication of the first study, except for the subjects and the type of meal. In the first study subjects consumed a rice meal and in the second subjects consumed a macaroni meal as preload at lunch time. Two hours after the preload consumption a buffet like test-meal was presented to the subjects.

Subjects

Thirty-nine subject (16 male and 23 female) participated in the rice study, and thirty-five subjects (17 male and 18 female) participated in the macaroni-study. Most subjects were students, had a normal weight and were not high restraint according to the Dutch Eating Behaviour Questionnaire (DEBQ) of Van Strien (1986). Every subject was paid for participation. Table 1 shows the main characteristics of the subjects of both studies.

The subjects were informed that the experiment was meant to investigate the effect of warm meals on hunger and satiety. Some subjects said to have noticed differences between the different meals, but post experimental briefing revealed that they did not know how many and which experimental manipulations were given. Before participation all subjects gave their informed consent. Both studies were approved by the Medical Ethical Committee of the Department of Human Nutrition.

Preloads

The preloads in this study consisted of commercially available deep-frozen meals, that only needed to be heated before consumption. These meals were Rice goreng (fried rice with meat and vegetables) and Macaroni with meat and

Table 1. Mean characteristics (and SD) of the participants of the rice-meal and the macaroni-meal study.

		RICE-MEAL				MACARONI-MEAL			
		Men (n=16)		Women (n=23)		Men (n=17)		Women (n=18)	
		Mean	(sd)	Mean	(sd)	Mean	(sd)	Mean	(sd)
Age	(years)	22	(3)	23	(6)	22	(2)	22	(3)
Height	(cm)	184	(5)	169	(5)	184	(4)	171	(6)
Weight	(kg)	69	(8)a*	62	(8)	76	(8)a*	61	(6)
BMI	(kg/m^2)	20	(2)b†	21	(2)	22	(2)b†	21	(1)
Body fat	(%) ‡	14	(4)	26	(4)	16	(4)	28	(3)
Restraint score §		1.4	(0.4)c†	2.4	(0.6)	1.9	(0.4)c†	2.3	(0.6)

* $p<0.05$, † = $p<0.01$; The same letter indicates a statistical significant difference between the same sexe.

‡ Fat mass was calculated by means of biceps plus triceps skinfolds according to the formula of Durnin and Womersly (1974).

§ The restraint score was measured with the DEBQ of van Strien (1986). The minimum value is 1 (no restraint), the maximum value is 5 (high restraint).

vegetables (of the brand IGLO options plus (IGLO-OLA B.V., Utrecht, The Netherlands)). These meals contained a small amount of fat (3 g fat/100 g), resulting in 28% energy from fat.

Six different preloads were given in both the rice- and macaroni-study, which only differed in fat and SPE content. The preloads were constructed in a way that three different series could be investigated. The first one was the SPE-series (i.e. water-, SPE/water- and SPE-preload) with equal energy contents but with different greasiness between the three preloads. The second series was the FAT-series (i.e. water-, FAT/water- and FAT-preload) with different energy contents and different greasiness. The third series was the SPE*FAT-series (i.e. SPE-, FAT/SPE- and FAT-preloads) with different energy contents but with equal greasiness. In this third series the effects on appetite and energy intake of the fatreplacer sucrose polyester (SPE) could be directly compared with the effects of fat.

As weight may act as a confounder on appetite, the addition of fat or SPE to the meals was paralleled by the addition of water, so that within each study all preloads had equal weight. In Table 2 the composition of the six preloads for both studies are listed.

We were aware that, because every subject received the same preloads, the energy content of the preloads were relatively large for women and not for men. We expected that if the subjects would detect post-ingestive differences between the preloads, they would compensate independently of the energy level of the preload.

Before the experiment started, it was determined empirically how much water was lost by heating, and how much fat or SPE was left on the plate after consumption of the preload. No differences in water loss were found between the preloads added with fat and the preloads added with water with an average of 6 g water loss per preload. For obtaining the desired manipulation, an additional 4 g of fat, SPE, water or a combination of these three substances was added, as this was the amount that remained on the plate after consumption. The SPE was made by the Unilever Research Laboratorium (Vlaardingen, The Netherlands). The fat was commercially available frying fat without protein, water, or flavours added (Albert Heyn, Zaandam, The Netherlands), and was similar to the SPE used, regarding melting point, appearance and sensory characteristics.

Table 2. The energy content and the macronutrient composition (weight, and percentage of energy) of the six rice-meals and the six macaroni-meals.

Preload	Weight	Energy		Fat		Protein		CHO		SPE		water added
	(g)	(MJ)	(kcal)	(g)	(%)	(g)	(%)	(g)	(%)	(g)	(%)	(g)
RICE-MEALS												
SPE	500	1.89	446	14	(28)	23	(20)	59	(52)	50	(0)	0
SPE/water	500	1.89	446	14	(28)	23	(20)	59	(52)	25	(0)	25
water	500	1.89	446	14	(28)	23	(20)	59	(52)	0	(0)	50
FAT/water	500	2.84	671	39	(52)	23	(14)	59	(35)	0	(0)	25
FAT	500	3.79	896	64	(64)	23	(10)	59	(26)	0	(0)	0
FAT/SPE	500	2.84	671	39	(52)	23	(14)	59	(35)	25	(0)	0
MACARONI-MEALS												
SPE	450	1.69	404	12	(27)	24	(24)	50	(50)	50	(0)	0
SPE/water	450	1.69	404	12	(27)	24	(24)	50	(50)	25	(0)	25
water	450	1.69	404	12	(27)	24	(24)	50	(50)	0	(0)	50
FAT/water	450	2.63	629	37	(53)	24	(15)	50	(32)	0	(0)	25
FAT	450	3.57	854	62	(65)	24	(11)	50	(23)	0	(0)	0
FAT/SPE	450	2.63	629	37	(53)	24	(15)	50	(32)	25	(0)	0

Test-meals

The test-meal was composed of attractive sweet and savoury snacks, fruits, and drinks. Drinks were semi skimmed milk, full fat chocolate milk, and orange juice. Fruits comprised apples, oranges and banana's. Sweet snacks included apple-pie, chocolate confectionery (e.g. mars and chocolate bars), vanilla custard with cream, fruit yoghurt, cake, and biscuits. Savoury snacks included different meat rolls, soft rolls with ham or cheese, and potato crisp. All test-meal products with their composition are listed in appendix A. The test-meal was presented in a buffet like manner, and subjects were free to eat as much or as little as they wanted.

Measurements

Eating behaviour characteristics of the subjects.

The Dutch Eating Behaviour Questionnaire (DEBQ) was used to obtain scores for restraint eating, external eating and emotional eating (van Strien, 1986).

Subjective feelings of hunger and satiety.

Six items on hunger and satiety were rated by means of a slash on a 150 mm visual analogue rating scale. The six items were: appetite for a meal; appetite for something sweet; appetite for something savoury; over-satiety (over-fullness); feeble, weak with hunger; appetite for a snack. One each of these terms was placed above the centre of each of the six visual analogue scales, which were anchored on the left and right with the terms weak and strong, respectively. Written and oral instructions were provided to the subjects about the meaning of these terms (Hulshof *et al.* 1993). "Appetite for a meal" refers to appetite for a complete meal, either a hot meal or a sandwich meal.

Energy intake

One of the major problems with respect to appetite research is an objective measurement of the spontaneous food intake of subjects. Ideal would be to weigh everything a subjects consumes, but this would very strongly interfere with the persons regular food intake. As there is no golden standard, the best method has to be taken with regard to the research question (Cameron & van Staveren, 1988).

In the present studies we wanted to investigate the effect of SPE on satiety (not satiation) (Blundell *et al.* 1992), and therefore we included a deprivation period of 2 hours to avoid that the appetite ratings and the test-meal intake were influenced by energy intake in between the preload and the test-meal. The test-meal was given to have a precise measurement of the food intake after the different preloads. After the test-meal the ad lib consumption was measured by food diaries to have a better measure for the subjects regular food intake when compared with the test-meal food intake (Cameron & van Staveren, 1988). With the food diaries and the used numbers of subjects we were able to find a difference of about 1 MJ (power=0.90, $P<0.05$).

The energy intake at the test-meal was calculated using the Dutch food composition table (NEVO, 1986). Every food product was weighed before consumption, and leftovers were weighed after the test-meal to obtain the weight of products consumed per subject.

The energy and nutrient intake during the remainder of the day was recorded by means of a food diary. Subjects were asked to record all the foods and drinks consumed during the day according to the instruction of the food diary. All the foods and drinks consumed during the warm evening meal had to be weighed to an accuracy of 2 g on electronic scales (Soehnle scalina, Soehnle-Waagen GMBH & Co, Murrhardt/Württ, Germany). The weight of the other foods consumed during the day were estimated by means of standards for household measures. In the normal Dutch diet, lunch and snack items usually consist of ordinary food items, of which the weight can be accurately estimated by standard household measures. This is usually not the case for the foods and drinks eaten at the warm meal.

The food diaries were checked and coded by experienced dieticians. In case of unclear food records subjects were asked about these by the dietitians within a week. Energy intake was calculated using the Dutch food composition table (NEVO, 1986).

Sensory perception and pleasantness

Subjects rated the visual attractiveness of the preload meals prior to preload consumption. Pleasantness and the perceived intensity of the preloads were rated according to seven attributes during and after consumption of the preload meals. The seven attributes were: sweetness, saltiness, sourness, bitterness, greasiness, crispness and wateriness. Ratings were made on 150 mm visual analogue rating scales. No significant differences were found for the four basic tastes. In Table 3 the relevant differences in sensory attributes are shown.

Table 3. The visual attractiveness, greasiness, wateriness and pleasantness of the 6 different preloads for the rice- and the macaroni-study (from 0 mm (weak) to 150 mm (strong)).*

	SPE (mm)	SPE/water (mm)	water (mm)	FAT/water (mm)	FAT (mm)	FAT/SPE (mm)
RICE-MEAL (n = 39)						
Visual attractiveness	87	89	82	86	89	85
Greasiness	123	102	44	81	109	116
Wateriness	61	79	95	94	77	67
Pleasantness	67	83	89	76	84	76
MACARONI-MEAL (n = 35)						
Visual attractiveness	57	71	85	70	67	70
Greasiness	134	112	51	80	116	126
Wateriness	50	62	80	75	77	58
Pleasantness	58	75	105	95	80	74

* The attributes that had significantly different ratings between the six preloads are presented in this table (all $p<0.01$). Only the visual attractiveness ratings of the rice study did not differ between the six preloads.

Procedure

The six different preloads per study were offered in a random sequence, that varied for each subject. Every subject received each preload on a different day, resulting in a within-subjects repeated measures design. Study days were always on Tuesdays and Thursdays to eliminate weekend effects. A test day was run before the first study day to familiarize the subjects with all the procedures of the experiment. The rice-study was done in April 1992 and the macaroni-study in May 1992, in a 4 week period for each experiment.

Subjects were asked not to eat or drink anything except water after 23.00 p.m. the previous evening. Before the study started every subject had to write down what he/she wanted to eat every morning before preload consumption at lunch time, and this was discussed with the dietitian. They were instructed to consume exactly the same foods and drinks until the preload consumption on every test day. Subjects consumed the preload lunch in the departmental dining room at 12.30 p.m..

During the 2 hour deprivation period between the preload meal and the test meal the subjects were not allowed to eat or drink except water. This was done to enable the temporal tracking of motivational ratings for this period without interference of energy consumption. After these 2 hours subjects composed and consumed their test-meal from a buffet at 14.30 p.m.. They were instructed to eat as little or as much as they wanted. After the buffet test-meal the subjects had to record the foods and drinks they consumed on the study day (day 1) and the day after the study day (day 2) in a food diary. Appetite ratings were recorded just before (12.30 p.m.) and just after (12.45 p.m.) the consumption of the preload, at 13.00 p.m., at 14.00 p.m., and just before the test-meal consumption (14.30 p.m.).

Data analysis

Ratings of hunger and satiety scores were read by an Optical Mark Reader, and converted into scores from 1 (weak) to 25 (strong). In this paper only the results on "appetite for a meal" are discussed as this is conceived as being similar to general appetite (de Graaf *et al.* 1992).

To enable one overall comparison of the effects of the six different preloads on "appetite for a meal", the area under the curve (AUC) was taken as the dependent variable (instead of the five scores on motivational ratings). One advantage of the area under the curve is that it gives one value, so that the effect of preloads can be compared directly with each other (instead of comparing curves). Another advantage is that this measure takes into account the magnitude of the different time intervals between the adjacent measurements (which is not the case for ANOVA with the absolute values). The disadvantage of this analysis is that the temporal tracking of the hunger and satiety feelings is missed (Hulshof *et al.* 1993).

The area under the curve was calculated as percentage of the total area (AUC%) by the following equation (see Figure 1):

(((1/8 (A+2B+5C+6D+2E))-2)/48)*100.

Where A, B, C, D, E, are the motivational ratings at 0, 15, 30, 90, and 120 min respectively. The lower the AUC% value for "appetite for a meal", the more satiating the preload is.

Statistical analysis for the effects of the preloads on AUC% and food intake were carried out with ANOVA for repeated measures using the SAS statistical software package (Statistical Analysis Systems, 1990), with the type of preload as the fixed within subject factor, and the subjects as the random factor.

The calculation of the percentages of energy for the macronutrients, were obtained by using the mean of the individual values.

To investigate whether there was a dose-response effect for the different energy levels of the preloads, regression coefficients were calculated for each individual for the FAT-series (i.e. the water-, water/FAT- and FAT-preload) and the SPE*FAT-series (i.e. the SPE-, SPE/FAT and FAT-preload). The negative value of the slopes of the regression equations gives the satiating efficiencies as described by Kissileff (Kissileff, 1984). If the mean of the individual regression coefficients were statistically significantly different from zero, then this would indicate energy compensation. As energy compensation was expected to be in one direction (i.e. negative slopes and thus positive energy compensation), one-sided t-tests were performed.

A probability of 5% was set as the criterion for statistical significance, for all statistical tests.

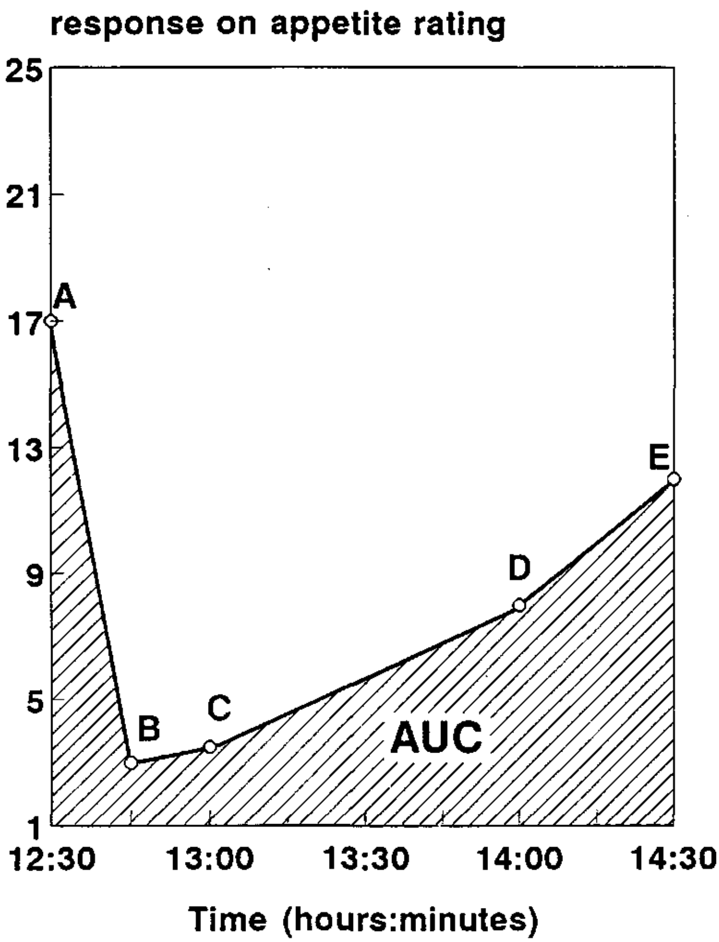

Figure 1. Illustration of the calculation of the area under the curve (AUC), using absolute appetite values. The AUC is calculated as the surface under the curve ((1/8(A + 2B + 5C + 6D + 2E)) minus the area between 0 and 1 **(time (14.30 h-12.30 h) * appetite (1-0) = 2)** divided by the total area **(time (14.30 h-12.30 h) * appetite (25-1) = 48)** and multiplied by **100%**. The result gives the area under the curve in percent of the total area (AUC%). A lower AUC% indicates a stronger suppression of appetite than a higher AUC%.

RESULTS

STUDY 1: THE RICE MEALS

Feelings of "appetite for a meal"

Figure 2 shows the area under the curve for appetite for a meal ratings from just before preload consumption to just before test-meal consumption in percent of the maximum area (AUC%) for men and women. The effect of preload was statistically significant for men [$F(5,75)=3.88$, $p=0.004$], but not for women [$F(5,110)=0.57$, $p=0.72$]. In men higher "appetite for a meal" ratings were found after the three lower energy preloads (i.e. SPE-, SPE/water-, water-preload) compared to the FAT/water- and the FAT-preload. The water-preload also resulted in higher ratings than the FAT/SPE- preload [all $F(1,15)>4.73$, all $p<0.05$].

Energy intake and energy compensation

The mean energy intake at the test-meal buffet, the total of day 1 (without and with the preload energy), and the total of day 2, as a function of the six preloads for the men and women of the rice study are shown in Table 4. No statistical significant differences were found for the energy intake at the test-meal, day 1 (without preload energy) and day 2.

When the total energy intake of day 1 was regarded (with preload energy) significant differences were found for women with higher intakes with the higher energy preloads, and lower intakes with the lower energy preloads. These differences in total energy intakes suggest that no energy compensation occurred, and that the differences were primarily due to the different energy levels of the preloads.

In men a similar pattern was found for the total energy intake of day 1 (with preload energy), with higher intakes with the higher energy preloads and visa versa. The differences in total energy intake on day 1 were smaller than the fixed energy differences of the preloads, and were not statistically significant. This could indicate that some energy compensation is occurring in men.

The mean of the individual regression equations between the energy levels of the preloads and the energy intake on day 1 after the preloads, for men and women of the rice study are shown in the left panel of Figure 4 for both the FAT-series (i.e. the water-, water/FAT-, and FAT-preload) and the SPE*FAT-series (i.e. the SPE-, SPE/FAT- and FAT-preload). For women of the rice study the regression

Table 4. The energy intake (MJ) at the test meal, day 1 (without and with preload energy), and day 2 for the six different preloads with water, SPE, or fat for the 16 men and 23 women of the **RICE-study**.

	SPE 1.9 MJ	SPE/water 1.9 MJ	water 1.9 MJ	FAT/water 2.8 MJ	FAT 3.8 MJ	FAT/SPE 2.8 MJ	ANOVA
E-I in Test-Meal:							
Men	5.0	4.7	4.8	4.4	4.8	4.7	$F(5,75)=0.31$ $p=0.9$
Women	2.8	2.6	2.7	2.6	3.0	2.3	$F(5,110)=0.88$ $p=0.5$
E-I DAY 1 without preload:							
Men	12.4	12.1	12.6	12.2	11.6	12.1	$F(5,75)=0.41$ $p=0.8$
Women	8.1	7.9	8.0	8.4	8.5	7.7	$F(5,110)=0.78$ $P=0.6$
TOTAL E-I DAY 1:							
Men	14.3	14.0	14.5	15.0	15.4	15.0	$F(5,75)=1.14$ $p=0.4$
Women	9.9	9.8	9.9	11.2	12.3	10.6	$F(5,110)=8.43$ $p<0.001$
TOTAL E-I DAY 2:							
Men	11.1	11.1	11.4	10.9	11.8	10.3	$F(5,75)=0.63$ $p=0.7$
Women	9.1	9.0	9.1	9.3	9.8	9.4	$F(5,110)=0.49$ $p=0.8$

E-I = energy intake

coefficients were positive with 0.14 [p=0.30] and 0.21 [p=0.19] for the FAT- and SPE*FAT-series respectively. For men statistically significant regression coefficients were found for the FAT-series with -0.67 [p=0.02] but not for the SPE*FAT-series with -0.41 [p=0.11].

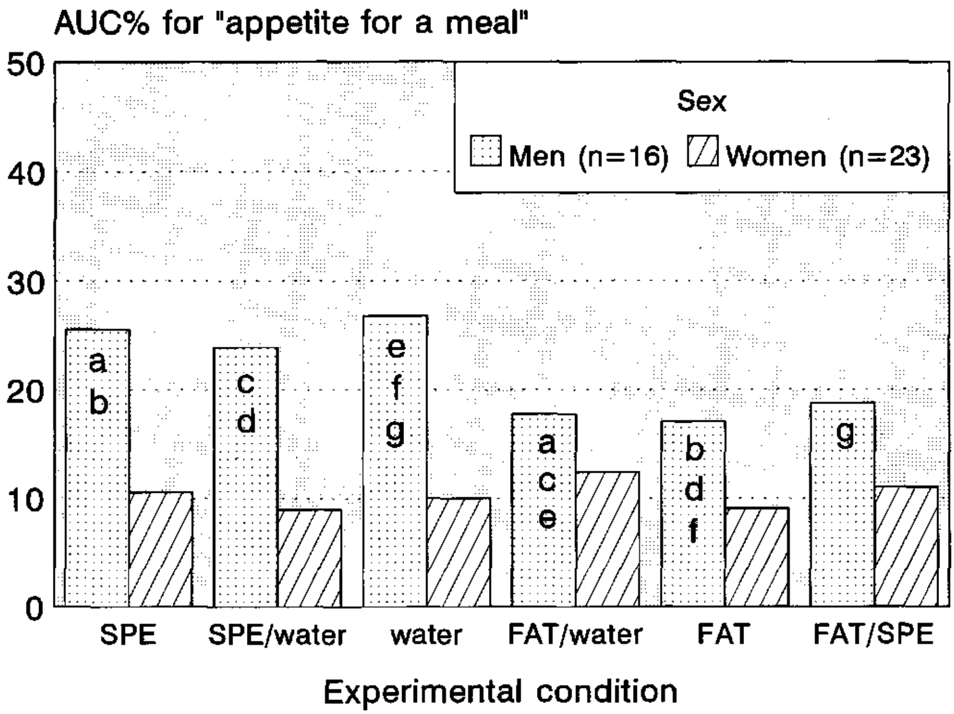

Figure 2. Mean area under the curve values for "appetite for a meal" in percentage of the maximum area for all six preloads, for the men and women of the **rice** study. The preloads were given at lunch time, followed by a deprivation period during which the subjects were not allowed to consume food until 2 hours after the appetite rating made just before preload consumption. Similar letters indicate a statistical significant difference between two preloads ($p<0.05$).

Macronutrient intake

When the macronutrient intake on the study day is regarded without the macronutrient intake of the preload, no statistical significant differences in macronutrient intake (as percentage of energy) were found between the six different experimental conditions in men [all $F(5,75)<2.23$, all $p>0.06$] or women [all $F(5,110)<1.91$, all $p>0.10$]. This suggests that no macronutrient specific compensation occurred. Men consumed on the study day (without preload intake values) on average 118 (SD 40) g fat, 84 (SD 27) g protein, 358 (SD 80) g carbohydrates and 11 (SD 16) g alcohol, whereas the women consumed on average 74 (SD 30) g fat, 59 (SD 17) g protein, 251 (SD 60) g carbohydrates and 5 (SD 12) g alcohol.

STUDY 2: THE MACARONI MEALS

Feelings of "appetite for a meal"

Figure 3 shows the area under the curve for the "appetite for a meal" ratings in percent of the maximum area (AUC%) for men and women of the macaroni study. There were no statistical significant differences between the six experimental conditions for the AUC% values of "appetite for a meal" for men [$F(5,80)=1.71$, $p=0.14$] or women [$F(5,85)=0.98$, $p=0.43$]. In men however, a similar pattern for the AUC% results as in the rice study was found, with higher appetite ratings after the lower energy preloads and lower ratings after the higher energy preloads.

Energy intake and energy compensation

The mean energy intake as a function of the six experimental conditions at the test-meal buffet, the total of day 1 (without and with preload values) and the total of day 2 for the men and women of the macaroni study are shown in Table 5. For women no differences between the six different preloads were found in energy intake at the test-meal, for the energy intake of day 1 (without preload energy) or the total energy intake of day 2. The total energy intake of day 1 (including the preload energy) was significantly different with higher energy intakes with the higher energy preloads. These differences seemed to be due to the different energy values of the preloads. As in the rice study there was no indication (in either the FAT-series or SPE*FAT-series), that women regulated their energy

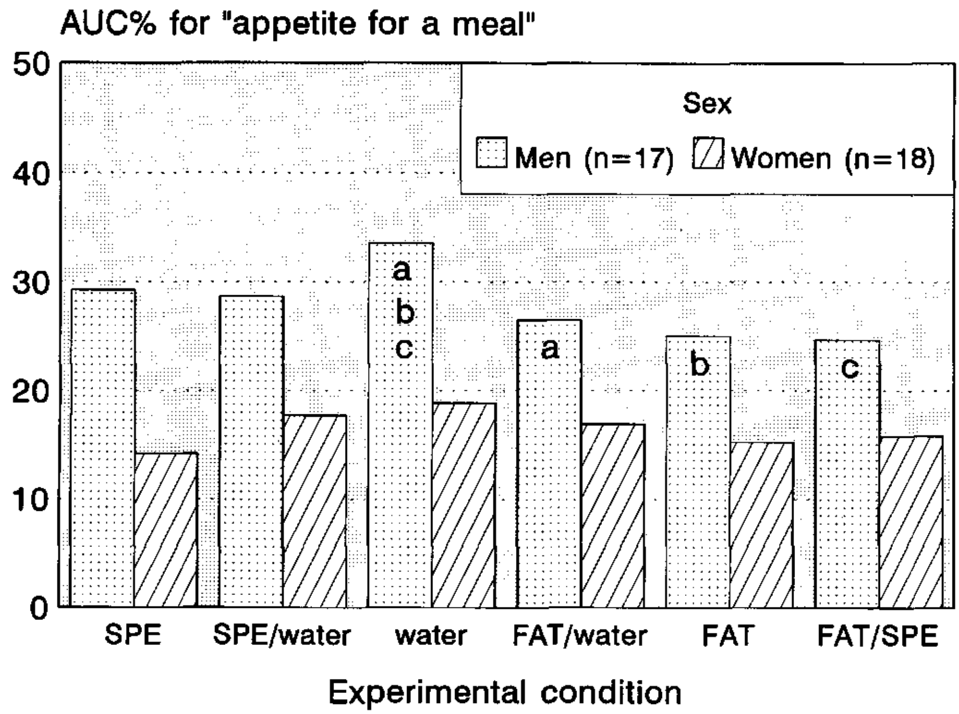

Figure 3. Mean area under the curve values for "appetite for a meal" in percentage of the maximum area for all six preloads, for the men and women of the **macaroni** study. The preloads were given at lunch time, followed by a deprivation period during which the subjects were not allowed to consume food until 2 hours after the appetite rating made just before preload consumption. Similar letters indicate a statistical significant difference between two preloads ($p<0.05$).

Table 5. The energy intake (MJ) at the test meal, day 1 (without and with preload energy), and day 2 for the six different preloads with water, SPE, or fat for the 17 men and 18 women of the **MACARONI-study**.

	SPE 1.7 MJ	SPE/water 1.7 MJ	water 1.7 MJ	FAT/water 2.6 MJ	FAT 3.6 MJ	FAT/SPE 2.6 MJ	ANOVA
E-I in Test-Meal:							
Men	6.6	7.2	6.9	6.7	5.6	5.9	$F(5,80) = 4.34$ $p = 0.002$
Women	3.2	2.9	3.0	3.0	3.0	2.6	$F(5,85) = 0.41$ $p = 0.8$
E-I DAY 1 without preload:							
Men	13.1	14.3	13.7	14.2	12.5	13.9	$F(5,80) = 2.29$ $p = 0.053$
Women	9.7	8.7	8.8	8.7	9.1	8.5	$F(5,85) = 0.72$ $P = 0.6$
TOTAL E-I DAY 1:							
Men	14.8	16.0	15.4	16.8	16.0	16.5	$F(5,80) = 2.47$ $p = 0.04$
Women	11.3	10.4	10.5	11.3	12.6	11.2	$F(5,85) = 2.89$ $p = 0.02$
TOTAL E-I DAY 2:							
Men	12.4	13.0	12.8	12.1	11.6	11.5	$F(5,80) = 1.05$ $p = 0.4$
Women	9.3	9.2	8.5	9.2	8.1	8.8	$F(5,85) = 1.06$ $p = 0.4$

E-I = energy intake

intake according to the energy levels of the preloads.

In men significant differences in energy intake were found between the six preloads at the test-meal, and for the total energy intake of day 1 (with preload energy). For the energy intake at the test-meal a dose-response reaction could be observed with regard to the energy levels of the preloads of the FAT-series (6.9, 6.7 and 5.6 MJ after the water-, FAT/water- and the FAT-preload respectively), with lower subsequent energy intakes after higher energy preloads [$F(2,32) = 5.37$, $p = 0.01$]. A similar dose-response effect was found at the test-meal with regard to the preloads of the SPE*FAT-series (6.6, 5.9 and 5.6 MJ after the SPE-, FAT/SPE-, and FAT-preload respectively) [$F(2,32) = 2.32$, $p = 0.07$]. At day 2 no statistically significant differences in energy intake were found for men.

The mean of the individual regression equations between the energy levels of the preloads and the energy intake on day 1 after the preloads, for men and women of the macaroni study are shown in the right panel of Figure 4 for both the FAT-series (i.e. the water-, water/FAT-, and FAT-preload) and the SPE*FAT-series (i.e. the SPE-, SPE/FAT- and FAT-preload). For women the regression coefficients were not statistically different from zero with -0.12 [$p = 0.37$] and -0.37 [$p = 0.15$] for the FAT- and SPE*FAT-series respectively. For men the regression coefficients were statistically significant from zero for the FAT-series with -0.65 [$p = 0.03$] but not for the SPE*FAT-series with -0.26 [$p = 0.21$].

Macronutrient intake

No statistically significant differences in macronutrient intake on day 1 without the preload values (as percentage of energy) were found between the six different experimental conditions in men [all $F(5,80) < 0.46$, all $p > 0.8$] or women [all $F(5,110) < 2.25$, all $p > 0.06$]. On day 1 men consumed (without preload values) on average 131 (SD 43) g fat, 90 (SD 26) g protein, 412 (SD 91) g carbohydrates and 10 (SD 17) g alcohol, whereas women consumed on average 78 (SD 36) g fat, 63 (SD 21) g protein, 285 (SD 72) g carbohydrates and 5 (SD 10) g alcohol.

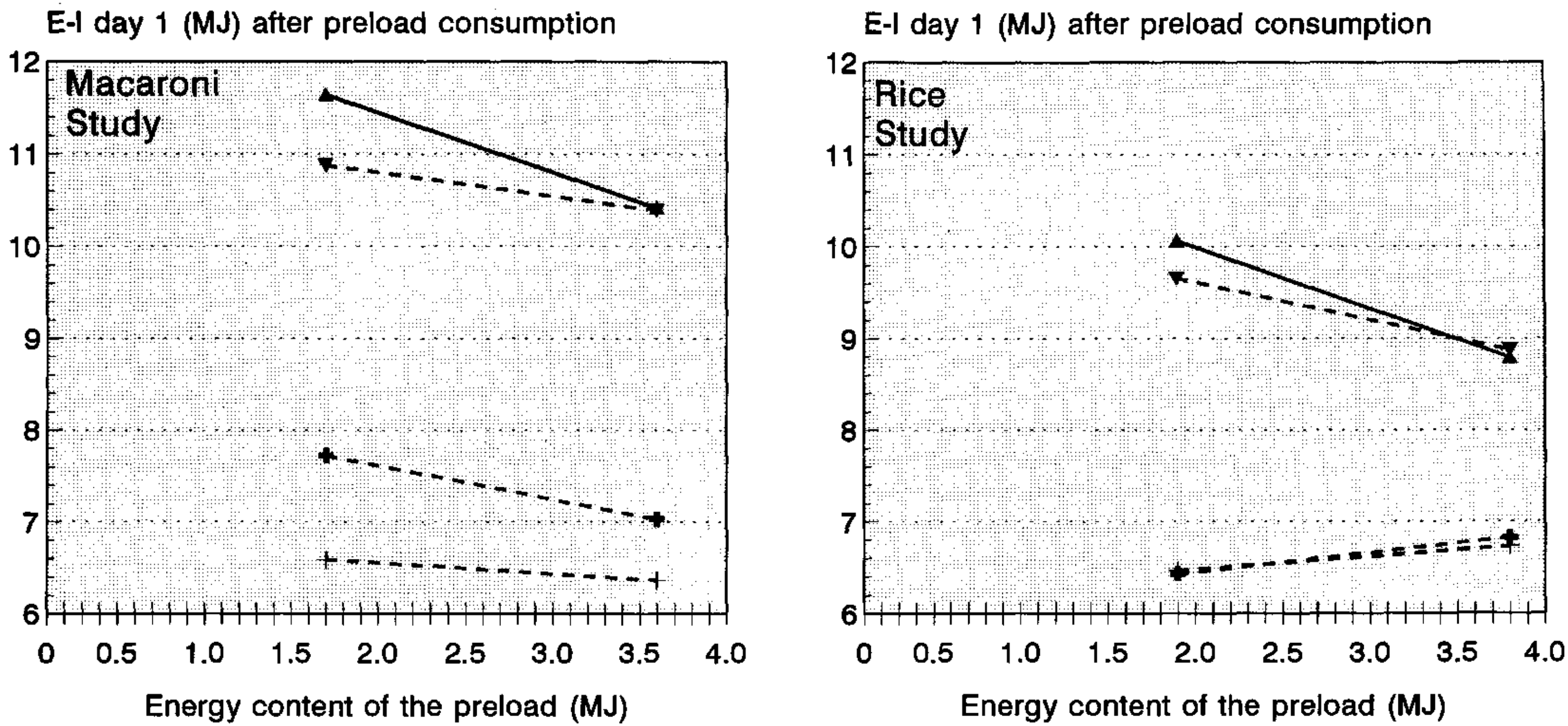

Figure 4. The mean of the individual regression equations with the energy content of the preloads as the dependent variable and the energy intake after the preloads on day 1 as the independent variable. The results of the rice study are shown in the left panel, and the results of the macaroni study are shown in the right panel. The regression equations for the FAT-series were calculated by using the water-, FAT/water- and FAT-preloads. The regression equations for the SPE*FAT-series were calculated by using the SPE-, FAT/SPE- and FAT-preloads. The dotted lines are slopes of regression equations that were not different from zero. The triangles represent the men with ▲ for the FAT-series and ▼ for the SPE*FAT-series. The plus signs represent the women with + for the FAT-series and ✚ for the SPE*FAT-series.

GENERAL DISCUSSION

The two present short term studies, that were replications, yielded similar results with respect to energy intake and appetite. Both studies show that the addition of about 50 g of water, fat or SPE to a warm lunch resulted in some differences in subsequent energy- and macronutrient-intake for men, but not for women. Women consumed similar amounts of food, independent of the preload they got. For men significant differences were found in energy intake between the six preloads. Significant energy compensation was found in the FAT-series but not for the SPE*FAT-series. No macronutrient specific compensation was found in either study. With respect to feelings of appetite, small but significant differences were found for men with higher appetite ratings after the lower energy preloads, whereas in women no differences were found. The differences in appetite were in line with the differences found in the energy intake.

Feelings of "appetite for a meal"

Similar patterns in appetite for a meal were observed in men and women of both studies, although the differences in men in the rice study were more pronounced than in the macaroni study. In women no differences in appetite were found between the preloads. It could be argued that these results were due to a floor effect. However, the response for an other appetite dimension ("oversatiety (overfullness)") showed also no statistical significant differences between the six preloads in either study [$p > 0.16$]. For "oversatiety (overfullness)" the floor effect could not be important as the average AUC% values were 24% and 44% for the women of the rice and macaroni study respectively. This suggests that the absence of differences in "appetite for a meal" ratings were not due to a floor effect.

It should be noticed that a difference of 1.9 MJ (450 kcal) in energy intake, which resembles about 20% of the normal daily intake, results in relatively small differences in appetite. The differences in AUC% between the FAT- and water-preload were on average 9% in men and only 2% in women. This small effect is in line with the results of other studies with fat and SPE (Rolls *et al.* 1992; Hulshof *et al.* 1993; Hulshof *et al.* 1993).

In both studies the appetite ratings seemed to be in line with the subsequent energy intake at the test-meal with higher energy intakes after higher appetite ratings.

Energy intake and energy compensation

In this study no effects on energy intake were found in women. They consumed similar amounts of energy on day 1 and day 2 independent of the experimental manipulation. In none of the two series where the preloads had different energy levels, described in the preloads section of the methods and materials (FAT-series, SPE*FAT-series) an effect of the energy level of the preload could be found on subsequent energy intake. In women energy compensation values were found between -21% and 37% (n.s.) of the energy differences between the preloads.

In men there were some differences in energy intake between the different experimental conditions. This seemed to be due to energy compensation. In this study the energy compensation could be found by taking the negative value of the slope, this was called the satiating efficiency by Kissileff (1984). A slope of -1 means that there is complete (100%) energy compensation, whereas a slope of 0 means no (0%) energy compensation. In men the regression coefficients of day 1 were statistically significant from zero for the FAT-series but not for the SPE*FAT-series. For the FAT-series energy compensation was similar for the rice and macaroni study with 67% and 65% respectively. For the SPE*FAT-series these values were lower with 41% and 26% energy compensation (n.s). This indicates that when fat is replaced by SPE no significant energy compensation was found in a group that showed energy compensation when fat was replaced by water. The main difference between the SPE*FAT-series and the FAT-series was the level of greasiness. It could be that these differences in greasiness resulted in the differences found between the two series, although the effects of the SPE-series (with no differences in energy intake) do not support this.

The results of the women are in line with the studies of Hulshof et al. (1993a, 1993b), Cotton et al. (1993) and Glueck et al. (1982), whereas the results of the men are more in line with Rolls et al. (1992) and Blundell et al. (1992). In the studies of Rolls et al. (1992) and Blundell et al. (1992) only men participated, as in the study of Cotton et al (1993). In the studies of Hulshof et al (1993a, 1993b) both sex were investigated and in the study of Glueck et al. (1982) there were only women. Therefore it is not clear if these differences are due to sex differences or due to differences in the methodological design.

It should be noted that although the "appetite for a meal" ratings were low, relatively much food was consumed by the women at the test-meal. This could be due to several reasons. First the subjects were obliged to come to the departmental dining room for the test-meal, and this could be an extra motivation to eat. Second, their "oversatiety (overfullness)" ratings were not high with 4.7 and 7.8 units just before the test-meal consumption. Although their appetite was not high, they were also not very full. The third reason is that the test-meal was a snack-meal. The mean of the individual correlations between "appetite for a snack" (r = 0.38), "appetite for something savory" (r = 0.28) and "appetite for something sweet" (r = 0.28) correlated higher with the subsequent energy intake at the test-meal than "appetite for a meal" (r = 0.16), "oversatiety (overfullness)" (r = -0.23) and "feeble, weak with hunger" (r = 0.14) in women.

Plus versus minus manipulation of the preload

According to the 1992 Dutch nutrition survey the average energy intake at lunch was 1.9 MJ and 2.9 MJ for women and men respectively (Voorlichtingsbureau voor de voeding, 1993). The three preload energy levels in this study were on average 1.8 MJ, 2.7 MJ, and 3.7 MJ. For women the 1.8 MJ preload was on average equal to their normal intake, the other two preloads were higher than their normal intake indicating on average a plus manipulation. In men, only the high energy preload was higher than their normal intake, whereas the low energy preload resulted in a minus manipulation. It could be argued that the difference in manipulation (plus versus minus) between men and women was one of the causes for the different results between the sexes (Mattes *et al.* 1988). Therefore the question arises whether the women would show energy compensation if the preloads would have been a minus manipulation for them.

Differences in energy intake between day 1 and day 2

When the total energy intake of day 1 (with preload energy) is compared with the total energy intake of day 2, large differences were found for both men and women in both studies. On day 1 significant more energy was consumed in both studies compared to day 2, by both men and women with 3.7 and 1.8 MJ respectively. These differences were mainly due to the relatively large preload + test-meal intake on day 1 compared to the more regular afternoon intake at day 2.

The methodological design with an attractive test-meal buffet at a snack moment seem to increase the total energy intake of that day. However, the results of the men do not indicate that this methodological effect influences the ability of the subjects to compensate for the differences in the energy content between the preloads.

Macronutrient intake

As in other studies (Rolls *et al.* 1992; Hulshof *et al.* 1993; de Graaf *et al.* 1992; Rolls *et al.* 1988), no macronutrient compensation occurred in the rice or macaroni study in men or women. Subjects did not consume less fat after the high fat preloads, nor did they eat more fat after the low fat preloads. This means that, even when energy compensation would be complete, the percentage of energy derived from fat decreases, when a fatreplacer like SPE is used (Beaton *et al.* 1992).

Cognition and duration of the manipulation

In the present study only the short term effects were investigated. This does not give an indication about the effects on the longer term. SPE will only be a useful aid to reduce fat and energy intake, when in the longer term no full compensatory response of energy or fat intake occurs. In the only long term study (20 days) with SPE of Glueck et al. (1982), no complete energy compensation was found, like the results of the women in the present study. However, more long term studies are required on the effects of SPE as a fat replacer, as only 10 obese women participated in the study of Glueck et al. (1982).

Another point is the knowledge of the subjects of the preload manipulation. In this study and in other studies on SPE (Blundell *et al.* 1992; Rolls *et al.* 1992; Hulshof *et al.* 1993; Hulshof *et al.* 1993; Cotton *et al.* 1993; Glueck *et al.* 1982) the subjects were unaware of the preload manipulation. When SPE is used as a fat replacer in food products, awareness of the energy reduction in products with SPE will generally be the case. As cognition can influence feelings of appetite (Wooley *et al.* 1972), this has to be taken into account.

Effects of differences in pleasantness and greasiness on appetite and energy intake.

In several studies the problem of differences of pleasantness on appetite and energy intake has been pointed out (Hill *et al.* 1984; Warwick *et al.* 1993). In the present study we had the opportunity to test the effects of differences in pleasantness and perceived greasiness on energy intake in the SPE-series (i.e. SPE-, SPE/water- and the water preload). In the SPE-series the energy levels of the preloads were constant, but there were significantly different pleasantness and perceived greasiness ratings between the three preloads.

No significant differences were found within the SPE-series with respect to appetite or energy intake. The correlations between the pleasantness or greasiness of the products, with energy intake at the test-meal or appetite ratings between the preload and the test-meal showed no relation in men or women (all r between -0.04 and 0.09, $p>0.21$). The only significant correlation found was in men between the pleasantness and appetite ratings (AUC%) with $r=0.21$ ($p<0.002$). These results indicate that differences in pleasantness or perceived greasiness of the preloads had no or minor effects on appetite, or the energy intake at a test-meal two hours later.

CONCLUSIONS

The present short term studies indicate that the replacement of fat by SPE does not result in any differences in energy intake or appetite feelings in women. In men also no statistical significant energy compensation was found when fat was replaced by SPE. This was true for a population that did compensate when the energy differences in the preloads occurred without addition of the fatreplacer SPE. The appetite feelings were in line with the differences in energy intake. The result was that in both men and women lower total energy intakes were obtained with the SPE-preloads compared to the FAT-preloads. No macronutrient compensation occurred. This means that even in case of complete energy compensation, the percent energy derived from fat will still decrease when using a fatreplacer like SPE.

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Appendix A. Energy content and the macronutrient composition of the products served in the buffet of the rice- and the macaroni study.

PRODUCT	Fat g/100g	PROTEIN g/100g	CHO g/100g	Energy kJ/100g
1 Semi skimmed milk	2.0	4.0	5.0	226
2 Full fat chocolate milk	4.0	4.0	10.0	385
3 Drinking yogurt	0.0	3.0	13.3	273
4 Orange juice	0.0	0.0	8.0	134
5 Curd with fruit taste	1.0	9.0	16.0	456
6 Whole milk yogurt	2.0	3.0	16.0	393
7 Custard (whole milk)	4.0	3.0	15.0	452
8 Apple with peel	0.0	0.0	10.0	167
9 Orange	0.0	0.0	10.0	167
10 Banana	0.0	1.0	22.0	385
11 Apple pie	25.4	6.0	53.7	1956
12 Dutch treacle wafer	28.0	5.0	52.0	2008
13 Cake with almond filling	24.0	5.0	48.0	1791
14 Fancy iced cake	13.4	3.4	61.1	1584
15 Cake with apple filling	17.1	10.8	61.2	1849
16 Mars bar	18.0	5.0	67.0	1883
17 Snickers	25.0	10.0	55.0	2029
18 Twix	25.0	6.0	62.0	2079
19 Raisin roll	3.0	7.0	50.0	1067
20 White roll ham	10.5	10.3	30.5	1078
21 Brown roll ham	9.2	10.3	27.9	986
22 White roll cheese	17.6	12.6	30.2	1379
23 Brown roll cheese	16.4	12.6	27.6	1290
24 Sausage roll	30.0	11.0	33.0	1866
25 Kroket *	18.0	7.0	23.0	1180
26 Fricandel *	23.0	15.0	9.0	1268
27 Potato crisp natural	37.0	5.0	46.0	2247
28 Potato crisp paprika	37.0	5.0	46.0	2247
29 Mayonnaise	80.0	1.0	2.0	3063
30 Mustard	4.0	5.0	6.0	335
31 Tomato ketchup	0.0	1.0	34.0	586

* Typical Dutch savoury snacks (kind of sausage roll)

CHAPTER 7

NON-ABSORBABLE FAT (SUCROSE POLYESTER) AND THE REGULATION OF ENERGY INTAKE AND BODY WEIGHT.

Toine Hulshof, Cees de Graaf, Jan A. Weststrate, Joseph G.A.J. Hautvast.

ABSTRACT

A substantial number of people have difficulties in controlling their body weight. The nonabsorbable fat-analogue sucrose polyester (SPE) has been proposed as a non-caloric fat substitute in low-fat products. SPE may affect food intake and body weight, and fat-soluble micronutrient status. We here report the first study on the longer-term effects of SPE on energy intake in normal weight subjects. We studied the longer term effects (12 days) of the consumption of warm meals with normal dietary fat (5.0 MJ, 1195 kcal) or meals where 52 g of fat was replaced by the fat-replacer sucrose polyester (3.1 MJ, 740 kcal) on spontaneous food intake, body weight and gastro-intestinal complaints in normal weight healthy male and female volunteers in two studies. In the first study the 48 subjects were unaware of the treatment, whereas in the second study the 47 subjects were informed what they received. In both studies men and women consumed less energy per day during the SPE- (11.2 MJ) compared to the fat-treatment (12.7 MJ) (p's < 0.0001) for the whole 12 day period. This was accompanied by equivalent changes in body weight. The percentage energy from fat decreased from 43% during the fat-treatment to 32% during the SPE-treatment. During the SPE-treatment more gastro-intestinal complaints and a higher frequency of defecation were reported. Information of the treatment did not affect the outcomes. The use of a non-absorbable fat-replacer such as SPE seems to help in reducing fat and energy intake, and body weight in normal weight people. These effects do not imply that SPE should be part of the food supply. Other effects e.g. on micronutrient status should also be considered.

INTRODUCTION

In Western Europe and Northern America both consumers and industry have a great interest in low-fat products. The number of Americans who consume low-calorie foods and beverages increased from about 40 million in 1978 to 100 million in 1991.[1] The food industry reacts, by strongly increasing the introduction of new products with reduced energy or fat content.[1] It is expected that the low-calorie market will grow strongly for the coming years.[1]

An important question with respect to the use of low-energy or low-fat products is the effectiveness: do people really consume less energy and fat when low-energy/fat products are part of their diet. Short term (one day) studies show controversial results from almost no compensation[2,3] to complete compensation[4,5] for the "missed" energy. In longer term studies (5[6], 14[7] and 77[8] days) where the effects of low- and high-fat diets on energy intake were investigated, complete energy compensation was never found.

Critical to the success of new low-caloric products is the ability to successfully replace the sensory attributes of fat by the use of low- or zero-calorie fat substitutes. Food companies are therefore active in developing improved low- or zero-calorie fat substitutes, produced both from existing food sources and from chemical synthesis. The latter compounds, so called fat-analogues, are designed to mimic natural fats and oils but they are partially or totally undigested. An interesting synthetic fat-analogue is exemplified by the non-toxic sucrose polyester (SPE). SPEs are fatty acyl esters of sucrose, predominantly the octa-ester, in which the fatty acyl chains are of the types familiarly found in edible oils and fats.[9] SPEs chemical and physical properties closely parallel those of triglycerides.[10] SPEs are neither broken down nor absorbed in the digestive tract.[11,12] They are thus a true non-caloric fat substitute and may be used as a good tool to investigate the effects of fat reduction on the regulation of food intake. Apart from its effects on food intake it should be recognized that SPE may adversely affect the absorption of fat-soluble micronutrients such as vitamin A and E.[10,13,14] These effects should be subject to critical evaluation of the long term safety for consumers of SPE.

With respect to the effects of SPE on food intake the question arises whether replacement of dietary fat by SPE causes increased energy and fat intake. So far, in the only long term study (20 days) where the replacement of fat by SPE on food intake was investigated, no energy compensation was found in 10 dieting obese subjects.[13]

In most studies in which the effects of different energy or fat levels of foods on subsequent food intake were investigated, the subjects were unaware of the energy manipulation. In daily life consumers will be informed by the food labelling, whether or not they buy and consume a low-fat or a normal-fat product. We investigated the longer term effects (12 days) of replacement of 52 g fat by 52 g SPE in the evening meal on food intake and consequently body weight in two studies. In the first study (No-Information-study) the subjects were unaware of the composition of the foods we provided them, in the second study (Information-study) the subjects were informed whether they had a normal or a light (SPE) menu. These studies are the first longer term studies where repeated replacement of fat by SPE in one single meal on food intake was investigated in normal weight male and female subjects.

METHODS

Subjects

We studied 95 healthy subjects in two investigations: 48 in the first and 47 in the second. All subjects were student at the Wageningen Agricultural University, and were recruited at the University by posters and leaflets. Subjects who restricted their food intake (a score > 3.24 on the Dutch Eating Behaviour Questionnaire (DEBQ)[15]) and subjects with a Body Mass Index (B.M.I.) > 26 kg/m^2 were excluded for participation. The health status of the subjects was obtained by a medical questionnaire. Women using contraceptive pills were excluded for participation.

Every subject was informed about the use of the fat-replacer sucrose polyester (SPE), and signed an informed consent before participation. Both studies were approved by the Medical Ethical Committee of the Department of Human Nutrition. Table 1 shows the main characteristics of the subjects of both studies.

Study design

The two studies had a cross over design, with two 12-days treatments. Half of the subjects started with 12 days consumption of the SPE-meals and the other half with 12 days the fat-meals. There were some differences between the two studies. The first study was in October and the second study in November/December, and there were different subjects for each study. The main

Table 1. Mean characteristics (and SD) of the men and women of both studies.

	No-Information-Study		Information-Study	
	Men (N = 28)	Women (N = 20)	Men (N = 27)	Women (N = 20)
age (years)	22 (3)	22 (2)	22 (3)	22 (3)
height (cm)	183 (8)	171 (7)	184 (7)	171 (6)
weight (kg)	72 (7)	64 (7)	73 (9)	65 (8)
BMI (kg/m^2)	21 (2)	22 (2)	22 (2)	22 (2)
Body fat (%)*	14 (4)	26 (4)	14 (4)	26 (4)
restraint†	1.6 (0.4)	2.3 (0.6)	1.7 (0.6)	2.3 (0.5)
Alcohol (#/wk)‡	6 (4)	3 (2)	10 (7)	3 (4)
Smoking (#/day)§	0 (0)	0 (0)	2 (4)	0 (1)
Sport (hrs/wk)	2.4 (2.0)	2.0 (1.5)	2.6 (2.2)	2.5 (1.3)

* Body fat percentage was calculated with the formula of Durnin and Womersley[40] for the sum of bicep and tricep skinfolds.

† The restraint score was measured with the Dutch Eating Behaviour Questionnaire of Van Strien[14]. The minimum value is 1 (no restraint), the maximum value is 5 (high restraint).

‡ Number of reported alcoholic consumptions per week (# = number).

§ Number of cigarettes per day (# = number).

difference was that the subjects in the second study (Information-study) were informed whether they received a menu with fat or with SPE, and this was not the case in the first study (No-Information study). In the Information-study daily information about the energy and macronutrient composition of the menu's was provided to the subjects orally, and by means of posters and leaflets in the dining room. Post experimental briefing revealed that 3 subjects of No-Information-study were aware of the experimental manipulation they received.

Subjects came for two times 12 consecutive days, starting on monday, to the departmental dining room to consume the manipulated three course evening meals. A washout-weekend was placed between the two 12 day treatment periods, during which the subjects had no restrictions. In both studies two different conditions of the evening meal were provided, one with 77 g of fat and one where 52 g fat was replaced by 52 g sucrose polyester (SPE) resulting in a 1.9 MJ (450 kcal) energy difference between the two conditions. The left part of Table 2 shows the average nutrient composition of both conditions, calculated with the Netherlands Nutrient Data Base.[16] Before both studies started a pilot study was performed with 10 subjects to test the 5-day tolerability of 50 g SPE in warm meals. This pilot study revealed that 50 g SPE was well tolerated by the subjects, when consumed on 5 consecutive days.

Subjects were asked to live their normal life without new extreme eating or exercise habits. They were also requested to go to bed before 01.30 a.m. and to get up before 09.00 a.m..

Duplicate portions of the fat and SPE condition for an imaginary participant were collected on every study day, stored at -20 degrees Celsius, and analyzed after the study. The right part of Table 2 shows the composition of the menu's obtained by chemical analysis.

Experimental meals

The experimental manipulation took place in the evening meals. There were six different three course evening meals, each containing a starter, a main course and a dessert. With the meals subjects consumed a standard amount of water. The energy manipulation was similar for each meal. The fat and SPE meals were similar in appearance and other sensory characteristics. The meals consisted of foods that were normal for a Dutch diet, and every course was served in the habitual portion size. Every subject received the same size of the three course meals. Meal number 1 consisted of tomato soup, fried rice with vegetables, and apricot curd tart. Meal

2 was composed of toast with russian salad, sauerkraut with potatoes, and cherry curd tart. Meal 3 was curry soup, fried pasta with vegetables, and custard with cake and fruit cocktail. Meal 4 consisted of bread with butter, kale with potatoes, and apple sauce. Meal 5 was made of bread with ragout, chili con carne, and custard with cake and tangerine. Meal 6 consisted of broccoli soup, macaroni with vegetables, and pear with chocolate sauce. The starters and deserts were made in the lab, whereas the main courses were deep frozen meals of the brand IGLO (IGLO-OLA B.V., Utrecht, The Netherlands).

Every meal was eaten four times by each subject. The sequence of the meals in the first 12-day period was similar to the sequence in the second 12-day period, but differed per study. The order of the meals was at random within every 6-day period with the restriction that between equal meals at least 2 other meals were consumed. On every Tuesday meal 2 was eaten and on every Thursday meal 4 was eaten.

Table 2. Mean energy and nutrient content of the FAT- and SPE-meals, averaged over the six different menu's, calculated by use of the Dutch food composition table[15] and by use of chemical analysis values.

	Food composition table				Chemical analysis			
	FAT-meals		SPE-meals		FAT-meals		SPE-meals	
	(g)	(E%)	(g)	(E%)	(g)	(E%)	(g)	(E%)
Protein	32	(10)	32	(17)	33	(11)	33	(18)
Carbohydrate	101	(33)	101	(53)	97	(32)	98	(53)
Fat	77	(57)	25	(30)	75	(56)	24	(29)
SPE	0	(0)	52	(0)	0	(0)	49	(0)
Energy (MJ)	5.13 MJ		3.17 MJ		5.00 MJ		3.10 MJ	
Energy (kcal)	1225 kcal		755 kcal		1195 kcal		740 kcal	

E% = Percentage energy derived from the macronutrients.

Measurements

Reported food intake

All food and drink intake, except for the warm evening meal that was provided by the investigator, were measured by means of a food diary. Subjects recorded the weight of most foods in household measures, the other foods had to be measured with an accuracy of 2 g on a scale that was provided to the subjects. The food diaries were checked every day by experienced dieticians. In case of unclear food records subjects were asked about this by the dietitians within a day. Afterwards the food diaries were coded by the same dietitians. Energy and macronutrient intake were calculated using the Netherlands Nutrient Data Base [16].

A major problem with respect to food intake research is to have an accurate measurement for the spontaneous food intake of humans. Ideal would be to observe and weigh everything a person consumes, but this would very strongly interfere with the regular spontaneous food intake. The doubly labelled water method can be used to measure the subjects total energy expenditure. When subjects are in energy balance, the doubly labelled water can be used as a reference for energy intake measurements. In several studies where dietary intake was compared with the doubly labelled water method, underreport of food intake was found.[17-20] Schoeler[21] however suggested that accurate results on energy intake measurements were found for non-obese adult subjects in industrialized countries.[22,23]

Body weight

Body weight without clothes was measured blind for the subjects on every study day just before the consumption of the three course evening meal with an accuracy of 0.1 kg (SECA delta, model 707, Germany).

Feelings of hunger and satiety and pleasantness ratings.

Feelings of hunger and satiety were rated hourly from 900 till 2200 hrs on every Tuesday and Thursday during the experiment by means of 150 mm visual analogue rating scales. Every Tuesday the same menu was given to avoid influences on feelings of appetite by the menu composition. This was also the case for every Thursday. There were six different appetite related items, appetite for a meal, appetite for something sweet, appetite for something savoury, oversatiety (overfullness), feeble weak with hunger, appetite for any snack. Written and oral instructions about the appetite items were provided to the subjects.[3]

Pleasantness ratings were made after the meal on a five point scale from 1 (very unpleasant) to 5 (very pleasant) for all three courses of the meal separately. The three ratings were averaged to obtain one value for a certain meal.

General health and clinical complaints

Every study day the subjects had to fill out a questionnaire just before they went to bed about their general wellbeing, health, intestinal complaints and number of defecations of that day.

Statistical Analysis

The data were analyzed with ANOVA and regression procedures of the Statistical Analysis System.[24] Regression analysis was used to investigate whether there was a time effect on the energy intake and body weight of the long term treatment. ANOVA was used to investigate treatment effects. Period effects or carry-over effects were tested with ANOVA as described by Jones and Kenward[25] by using the mean energy intake per treatment period for each subject. In the No-Information-study no period or carry-over effects were found for energy intake in men or women. In the Information-study no carry-over effects were found for men or women, and no period effect for men. A significant period effect was found for the energy intake in women of the Information-study. As this period effect was weak compared to the treatment effect, and did not result in different conclusions on energy intake, we decided to pool the data of the two periods.

Differences in energy intake or body weight were calculated per subject and per day, by subtracting the values of day X of the SPE-period from day X of the fat-period (X is 1 to 12). Energy compensation was calculated as a measure to determine how much of the energy deficit due to the replacement of 52 g fat by 52 g SPE (1.9 MJ, 455 kcal), was compensated for. For each individual energy compensation was calculated as the negative value of the slope between the preload energy values and the subsequent energy intakes on the different treatments, as was described by Kissileff[26,27]. In this way one value for energy compensation was obtained for each subject. Energy compensation was analyzed by testing whether the mean of the individual energy compensation values differed from zero with a paired t-test. The expected weight change (kg) was calculated as: Cumulative energy difference between the fat- and SPE-condition (over 12 days) in MJ divided by 29 MJ (6900 kcal)[28].

Ratings of hunger and satiety were read by an Optical Mark Reader and converted into scores from 1 (weak) to 25 (strong). Within subjects ANOVA was used to compare the mean appetite ratings of the SPE-period with the mean rating of the fat-period.

Statistical significance was set at the 0.05 level. All analysis were performed for men and women of both the No-Information-study and the Information-study.

RESULTS

In both studies 48 subjects entered for participation. One person in the Information-study did not start on the first day of the experiment, the other 95 subjects completed their study. The 95 subjects consumed every day all courses of the provided meals without leaving leftovers.

Energy and macronutrient intake

The mean total energy and macronutrient intakes for men and women of the two studies are shown in Table 3. In the No Information study both men and women consumed on average more energy per day during the fat- compared to the SPE-period. The differences were 1.85 MJ (440 kcal, $p<0.0001$; 95% CI, 1.48 to 2.22 MJ) and 1.54 MJ (370 kcal, $p<0.0001$; 95% CI, 1.20 to 1.87 MJ) respectively. As the diet manipulation between the fat- and SPE-period was fixed at 1.90 MJ per day, men took daily 0.05 MJ extra during the SPE-period besides the diet manipulation, and women 0.36 MJ. This means that energy compensation reached mean values of 3% in men ($p=0.77$; 95% CI, -15 to 21%) and 19% in women ($p=0.10$; 95% CI, -4 to 42%).

In the Information study the daily mean energy intake was also higher during the fat- compared to the SPE-period, with 1.03 MJ in men (245 kcal, $p<0.0001$; 95% CI, 0.66 to 1.40 MJ) and 1.63 MJ in women (390 kcal, $p<0.0001$; 95% CI, 1.32 to 1.94 MJ). Besides the diet manipulation men took in this study daily 0.87 MJ extra during the SPE-period and women 0.27 MJ. As a consequence energy compensation reached mean values of 46% in men ($p<0.0001$; 95% CI, 26 to 66%) and 14% in women ($p=0.20$; 95% CI, -8 to 37%).

Figure 1 shows the mean total energy intake for both studies, per study day for the SPE- and fat-condition and both sex. The left panel are the results of the No-Information-study and the right panel the results of the Information study.

Table 3. Mean daily intake of energy and macronutrients of subjects in the No-Information-study and the Information-study for men and women on the fat- and SPE-manipulation.*

	NO-INFORMATION-STUDY			
	Women (n=20)		Men (n=20)	
	SPE	FAT	SPE	FAT
Energy (MJ/day) †	9.23 ±2.5	10.77 ±2.3	12.50 ±3.0	14.35 ±3.0
Energy (kcal/day)	2205	2575	2990	3430
Macronutrients (g/day)				
Protein	72	71	99	98
Fat †	79	127	107	163
Carbohydrate	295	281 ‡	380	365 ‡
Alcohol	4	3	15	15

	INFORMATION-STUDY			
	Women (n=20)		Men (n=27)	
	SPE	FAT	SPE	FAT
Energy (MJ/day) †	9.27 ±2.3	10.90 ±1.9	12.80 ±2.9	13.83 ±2.8
Energy (kcal/day)	2215	2605	3060	3305
Macronutrients (g/day)				
Protein	75	72 ‡	95	91 ‡
Fat †	77	125	110	151
Carbohydrate	295	286	383	359 ‡
Alcohol	6	7	22	21

* The mean daily energy intake is the ad libitum energy intake as measured by the food diaries plus the energy intake in the experimental meal as calculated by chemical analysis.

† Both the total daily fat and energy intake differed significantly ($p<0.0001$) between the SPE- and fat-condition in the two studies and for both sex.

‡ Significant difference between fat- and SPE-condition $p<0.05$.

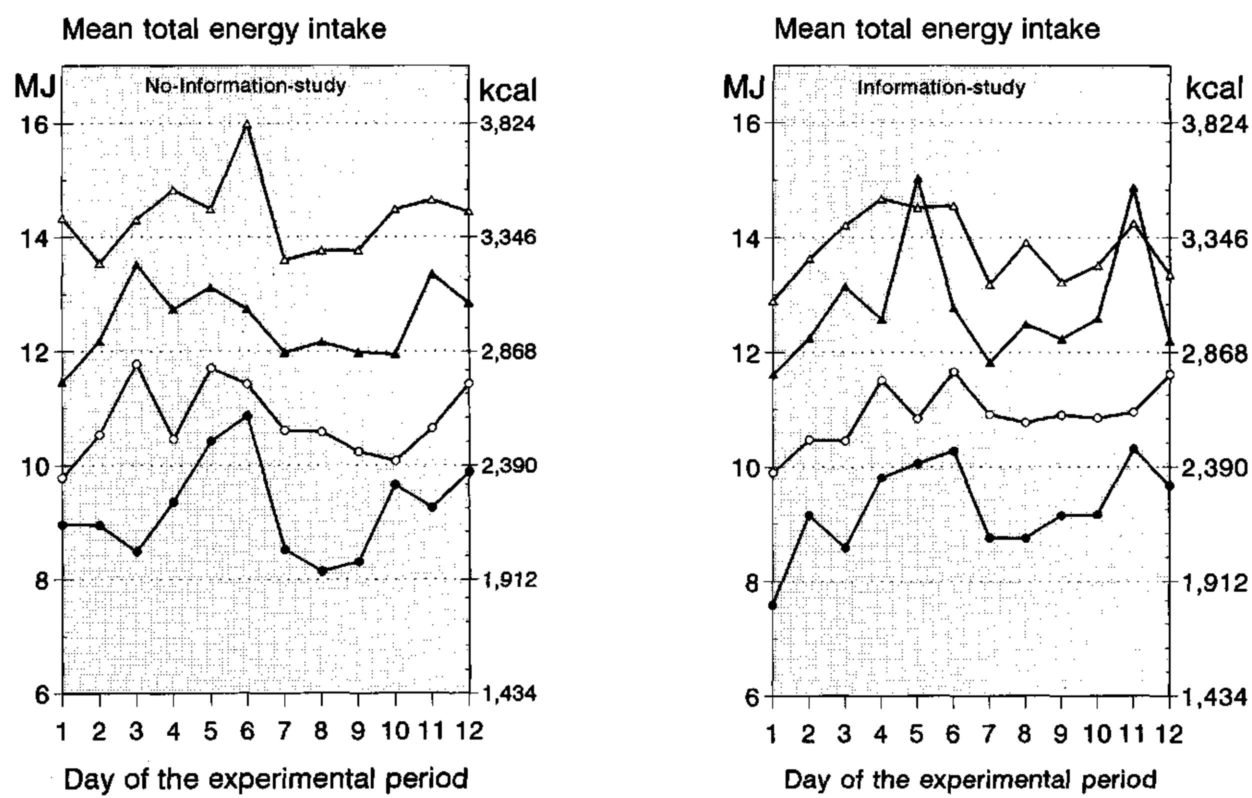

Figure 1. Mean total energy intake (MJ/kcal) during the fat- (open symbols) and SPE-treatment (closed symbols) for men *(triangles) and women (circles) for the 12 day period. The left panel shows the energy intakes of the No-Information-study where* the subjects were not aware of the experimental manipulation, the right panel shows the energy intakes of the Information-study where the subjects were informed what they were receiving. The mean total energy intake was calculated as the sum of the *energy intake with the experimental dinner meals and the ad libitum energy intake.*

Higher energy intakes were observed on the fat- compared to the SPE-condition for each study and sex. Only for the men of the Information study, two study days showed higher energy intakes with the SPE-condition than with the fat-condition.

Regression analysis revealed that there were no significant time effects on energy intake for men or women within the 12 day period for the fat- or SPE-condition of the No-Information-study (p's>0.58). The men of the Information-study also showed no time effect (p's>0.24), but in women a statistical significant increase in energy intake occurred in both the fat (77 kJ/day, p=0.03; 95% CI, 8 to 146 kJ/day) and the SPE-condition (100 kJ/day, p=0.02; 95% CI, 19 to 182 kJ/day). The slopes between the fat- and SPE-condition did however not differ (23 kJ/day, p=0.61; 95% CI, -114 to 67 kJ/day) indicating that energy compensation was not changing over time. There was no change in macronutrient compensation over time in either study or sex (all p's>0.12).

The replacement of fat by SPE resulted in a strong decrease in the percentage energy from fat in both studies and sex (all p's < 0.0001) from on average 43% to 32%. This was accompanied by increases in percentage energy from protein from 11% to 13% (all p's < 0.0001), and carbohydrate from 43% to 52% (all p's < 0.0001). When the fat intake was regarded without the intake of the manipulated warm evening meals, equal percentages energy from fat were found with mean values for both studies and sex of 32% in both the SPE- and fat-condition. This means that after the consumption of the SPE meals no specific fat compensation occurred (p's>0.09). No specific macronutrient compensation was found for protein, carbohydrates and alcohol (p's>0.09).

No substantial differences were found between the No-Information-study and the Information-study that could indicate a main effect of information on energy or macronutrient intake.

Body weight

The difference in cumulative energy intake between the SPE- and fat-condition gives an indication for the expected weight change. Gaining or loosing 1 kg body weight by fat tissue costs roughly 29 MJ[28] (6900 kcal). When the cumulative energy intake differences between the fat- and SPE-treatment over the 12 day period are known, then the expected weight change can be calculated by dividing the cumulative energy difference (MJ) by 29 MJ. Figure 2 shows the cumulative energy difference, and the observed weight change between the fat- and the SPE-treatment for the 12-day period.

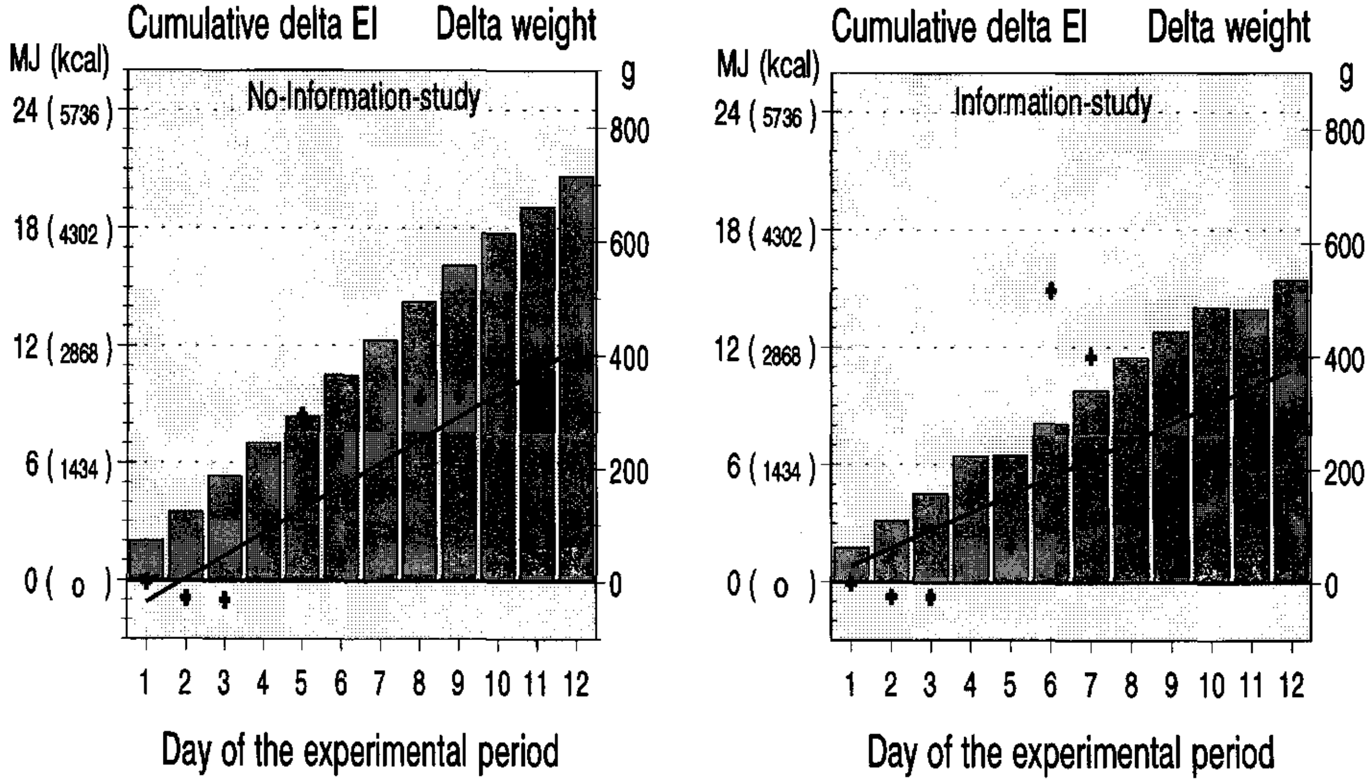

Figure 2. Mean cumulative energy intake differences (MJ, kcal) between the fat and SPE-treatment for the 12 study days (bars), combined with the observed weight changes (g) between the fat- and SPE-treatment (plus signs, and regression line). The differences in energy intake or body weight were calculated by subtracting the values of day X of the SPE-period from day X of the fat-period (X is 1 to 12). The magnitude of the Y-axis are chosen in order to be able to compare the observed weight changes directly with the cumulative energy differences which are a measure for the expected weight changes (expected weight change (kg) = cumulative energy difference (MJ) / 29 MJ)[28].

Regression analysis revealed that the expected weight changes were 60 g/day (95% CI, 53 to 66 g/day) for the No-Information-study and 44 g/day (95% CI, 37 to 51 g/day) for the Information-study. The observed weight changes were 41 g/day (95% CI, 19 to 63 g/day) for the No-Information-study and 31 g/day (95% CI, 8 to 55 g/day) for the Information-study. No differences were found between the expected weight changes and the observed weight changes in both the No-Information study (19 g/day; 95% CI, -3 to 41 g/day) and the Information-study (13 g/day; 95% CI, -11 to 36 g/day). This indicates that the differences in energy intake were in line with the observed weight changes.

When comparing the No-Information-study and the Information-study on body weight, similar results were found with about 70% of the energy differences covered by body weight changes in both studies.

Feelings of appetite and pleasantness

No statistically significant differences were found for any of the six appetite items averaged over the 16 measurements per day between the fat- and SPE-condition in the Information-study. Also similar appetite ratings between the fat- and SPE-condition were found for the men of the No-Information-study. However for the women of the No-Information-study the six appetite items were higher with the SPE compared to the fat condition, with statistical significant differences for "appetite for a meal" ($p=0.001$; 8.6 vs 7.5), "appetite for something sweet" ($p=0.02$; 9.3 vs 7.8) and "appetite for a snack" ($p=0.02$; 9.4 vs 8.4).

No time or condition effect on the sensory pleasantness of the meals occurred. The mean pleasantness ratings of the three course meals were similar for the first six meals and second six meals within the 12 day experimental period, with ratings of 3.6 for both six day periods. Also similar ratings for pleasantness were found for men and women for the fat and the SPE meals with mean ratings of 3.6 for both sex in both conditions.

Gastro-intestinal complaints

The main differences in gastro-intestinal complaints between the fat and the SPE condition occurred in gut rumbling, gut cramps, flatulence and diarrhoea in both studies. The frequency of any reported complaint (ranging from "a little" to "very much") for gut rumbling, gut cramps, flatulence and diarrhoea were on average 29%, 14%, 57% and 14% for the SPE condition compared to 8%, 4%, 27% and 1% for the fat condition. However, general wellbeing was similar during the fat- and SPE-condition with 2.1 and 2.2 respectively on a scale from 1 (very good) to 5 (very bad). The SPE addition to the menu's increased the defecation frequency from 1.5 times per day to 2.2 times per day.

DISCUSSION

These long term studies show that a substantial replacement of fat in equally palatable hot meals by a non-absorbable fat-replacer such as SPE reduces energy and fat intake both in blinded and in informed male and female subjects. The subjects consumed about similar amounts of fat and energy besides the experimental meals. Mean energy compensation for all subjects was 21%. There was no time effect in energy compensation. This means that during the last days of the 12 day study period the energy compensation was the same as it was the first days. No macronutrient specific compensation occurred and therefore the percentage energy derived from fat decreased from 43% in the fat-condition to 32% in the SPE-condition. This was mainly due to the fat differences in the experimental conditions. The differences in cumulative energy intake between the fat- and SPE-condition were accompanied by equivalent changes in body weight, both in the No-Information-study and the Information-study.

Table 4 shows the energy compensation values for both studies and sex, plus a value for the men of the Information-study, analyzed without the two days of excessive alcohol intake during the SPE-period. The relatively high alcohol intake was due to several parties by one third of the male subjects. Without the two days with excessive alcohol, energy compensation decreased from 46% to 29%. The low energy compensation is in line with the longer term studies of Glueck et al.[13] (20 days) and Lissner et al. [7] (14 days) and was less consistent with the short-term SPE studies (1 day) of Rolls et al.[4] and Blundell et al.[29] where, at least for the high SPE use, almost complete energy compensation was reported. In addition our results indicate that energy compensation did not change over time, however the present studies may have been too short to detect this.

Mattes et al.[30] and Foltin et al.[31] found no energy compensation when the manipulated energy intake was higher than the subjects' habitual energy intake (<20% energy compensation), whereas significant energy compensation was found when the manipulated energy intake was lower than the subjects' habitual energy intake (>50% energy compensation). In the second Dutch National Food

Table 4. Mean energy compensation values for both sex of the No-Information-study and the Information-study.

	Male			Female		
	EC%*	(95% CI)	P	EC%*	(95% CI)	P
STUDY						
No-Information	**3**	(-15 to 22)	0.77	**19**	(-4 to 42)	0.10
Information	**46**	(26 to 66)	<0.0001	**14**	(-8 to 37)	0.20
	29†	(8 to 50)	0.007			

* EC% = percentage energy compensation during the SPE- compared to the fat-period, with 95% confidence interval (95% CI) and p-values (P). The energy compensation was calculated as the negative value of the slope between the preload energy levels and the ad libitum dietary intake[25,26].

† This value for energy compensation was calculated by leaving out the two days of excessive alcohol intake during the SPE-period and their parallel days of the fat-period (i.e. the first monday and the second friday of both periods).

Consumption Survey of 1992[32] the average energy intake at dinner time, for Dutch men and women of the same age-group as the present subjects, was 3.8 MJ (910 kcal) and 3.0 MJ (715 kcal) respectively. This indicates that for women of the present study the dinner in the SPE-condition (3.1 MJ, 740 kcal) was equal to the average Dutch intake, and a surplus of energy was consumed in the fat-condition (5.0 MJ, 1195 kcal). For men the average Dutch energy intake at dinner was in between the energy levels of the two experimental conditions. The relatively high energy levels of the manipulated dinner meals, compared to the average Dutch dinner intakes, could as hypothesized by Mattes et al.[30] and Foltin et al.[31] be a possible explanation for the relatively low compensation levels found in the present studies.

No macronutrient specific compensation occurred in either study or sex. This means that the energy derived from fat decreased from 43% during the fat-treatment to 32% during the SPE-treatment. This was solely due to the difference in fat content between the fat- and SPE-condition. Macronutrient intake did not change over the 12-day period, so the percentage energy derived from fat remained low during the SPE-period. In other short term studies[2,33] no macronutrient compensation was also found. This implies that even if, in the long run, complete energy compensation would be reached, the percentage energy obtained from fat would still be reduced. A reduction in fat intake is in line with the health recommendations and could help to improve health in the long run.

The body weight of the subjects seemed to change according to the cumulative energy differences over the 12 days. This finding supports the validity of the energy intake values obtained by the food diaries in the present studies. The slopes of the observed weight changes were at a lower level compared to the slopes of the expected weight changes. This might be due to regular day to day variation in body weight, or due to the fact that the 29 MJ/kg to loose 1 kg of body weight is not the correct value to apply for the present studies. Bouchard et al.[34] found in an overfeeding study that a surplus of energy was not always followed by body weight gain, possibly due to energy dissipation. It might be that in the present studies some energy dissipation occurred during the fat-period.

In the SPE-condition more gastro-intestinal complaints and defecations were found compared to the fat condition. These complaints mainly concerned the gut, such as gut rumbling and cramps, flatulence and diarrhoea, and not the stomach. In the long term study (20 days) of Glueck et al.[13], where 10 obese subjects received on average 60 g SPE per day, no consistent changes in bowel function or gross stool composition during the SPE substitution period were found. This could be due to differences in the type of SPEs used, differences in study population (obese vs lean subjects) or because they did not ask specifically for gastro-intestinal complaints.

In many experiments in which the effects of an energy manipulation on subsequent food intake were investigated, the subjects were unaware of the experimental manipulation. In daily life however, most people know whether a low-energy (low-fat) or a normal product is bought and consumed. Therefore we considered it important to address this topic in our study. Providing information of the energy content of products affected energy compensation in some studies[35], but not in others[36,37]. In our informed women showed similar responses in food intake as non-informed women. Rolls et al.[37] found also no differences in energy compensation between informed and uninformed men and women. In the present studies uninformed men showed no energy compensation, whereas significant energy compensation was found for men who were informed about the energy content of the meals. However, the informed men did not compensate for more than half of the energy difference between the fat- and SPE-treatment. This indicates that the daily energy intake would decrease on the SPE-treatment.

We conclude that the replacement of fat by a fat-replacer like SPE can help in reducing fat and energy intake on a longer term basis. However, the long term safety of SPE *is also determined* by *other nutritional effects*, *such as on fat-soluble* micronutrient status. These effects should also be considered before deciding on the market introduction of SPE.

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CHAPTER 8

GENERAL DISCUSSION

The main objective of the studies described in this thesis was to determine the effects of the consumption of different amounts of fat on subsequent energy intake and appetite feelings. The synthetic fat replacer sucrose polyester (SPE) was used to prepare foods that were different in energy and fat content, but similar in taste and appearance. One of the main questions was whether or not subjects compensated for the energy differences, that were obtained by the replacement of fat by SPE. Also some methodological issues were investigated.

MAIN FINDINGS

The eight different studies described in this thesis showed that the majority of the normal weight men and women showed little or no compensation for energy differences in meals (preloads). For most of the individuals, food intake regulation was imprecise. No or small differences in appetite feelings were found when the energy manipulations were carried out (c)overtly in normal food products. Only when artificial (i.e. unidentifiable formula foods) preloads were used, lower preload energy levels resulted in higher hunger ratings.

The present studies show that normal weight men and women do not, or poorly recognize energy differences of foods, and poorly compensate for an energy manipulation, in their subsequent intake.

ENERGY AND MACRONUTRIENT INTAKE

Energy compensation

Each of the eight studies in this thesis was designed to determine the effect of a fixed energy/fat manipulation on subsequent energy/macronutrient intake. This allows for a meta-analysis on the issue of energy compensation. A meta-analysis has the advantage of greater statistical power and gives the possibility to investigate whether certain trends could be found for the total study population of the eight studies.

Table 1. Mean subject characteristics (sd), energy compensation and energy intake, per study and sexe for the 8 studies of the present thesis.

Study (N)	Sex	Age (years)	B.M.I. (kg/m²)	Restraint score (DEBQ)*	Energy compen. (%)†	E-I day 1 (-PL)‡ Mean (MJ)	E-I day 1 (-PL)‡ wis-sd ‖ (MJ)	E-I day 1 (+PL)‡ Mean (MJ)	E-I day 1 (+PL)‡ wis-sd ‖ (MJ)	E-I day 2§ Mean (MJ)	E-I day 2§ wis-sd ‖ (MJ)
1 (29)	women	21 (1)	21.1 (1.9)	2.6 (0.7)	21 (98)	8.64	1.95	9.58	2.00	-	
2 (33)	women	21 (2)	21.2 (1.5)	2.7 (0.8)	5 (69)	8.38	1.99	10.19	2.34	9.13	1.97
3 (17)	men	22 (2)	21.0 (1.6)	1.5 (0.4)	-16 (108)	11.15	2.42	13.68	2.58	12.65	2.90
(16)	women	22 (2)	21.7 (2.8)	2.5 (0.7)	27 (68)	7.17	1.60	9.69	1.72	8.84	2.05
4 (16)	men	22 (3)	21.4 (1.4)	1.6 (0.4)	20 (122)	10.44	2.32	12.96	2.44	12.59	2.44
(18)	women	22 (1)	21.1 (1.7)	2.5 (0.6)	15 (59)	7.19	1.33	9.71	1.48	9.86	2.02
5 (16)	men	22 (3)	20.3 (2.2)	1.4 (0.4)	5 (119)	12.16	1.89	14.68	1.88	11.08	2.46
(23)	women	23 (6)	21.5 (2.1)	2.4 (0.6)	-22 (88)	8.10	1.44	10.63	1.70	9.28	1.84
6 (17)	men	23 (2)	22.3 (2.1)	1.9 (0.4)	46 (75)	13.56	1.82	15.90	1.82	12.19	2.18
(18)	women	22 (3)	20.8 (1.3)	2.3 (0.6)	12 (105)	8.84	1.82	11.16	1.93	8.80	1.94
7 (28)	men	22 (3)	21.4 (1.8)	1.6 (0.4)	3 (47)	9.34	2.36	13.38	2.54	-	
(20)	women	22 (2)	22.0 (2.1)	2.3 (0.6)	19 (49)	5.91	1.87	9.95	2.04	-	
8 (27)	men	22 (3)	21.8 (1.7)	1.7 (0.6)	46 (50)	9.21	2.43	13.27	2.43	-	
(20)	women	22 (3)	22.0 (2.3)	2.3 (0.5)	14 (48)	6.00	1.72	10.04	1.90	-	
Totals per sexe:											
(121)	men	22 (3)	21.4 (1.9)	1.6 (0.5)	18 (87)	10.68	2.24	13.87	2.32	12.14	2.50
(177)	women	22 (3)	21.4 (1.9)	2.5 (0.7)	10 (76)	7.65	1.75	10.11	1.49	9.18	1.96
Totals all studies:											
(298)	m&w	22 (3)	21.4 (1.9)	2.1 (0.7)	14 (81)	8.88	1.95	11.63	2.09	10.30	2.16

* The restraint score was obtained by using the Dutch Eating Behaviour Questionnaire (DEBQ) by Van Strien.[30]

† The energy compensation was calculated as the negative of the slope between the preload energy levels and the subsequent energy intake, as was described by Kissileff[1].

‡ The energy intake of the study day (day 1) without preload energy (-PL) and with preload energy (+PL).

§ The total energy intake of the day after the study day (day 2).

‖ wis-sd: The mean of the within subjects standard deviation.

Table 1 shows the mean energy compensation, energy intake and subjects characteristics for each study per sex and for the 8 studies of the thesis together. For the meta-analysis one single figure for energy compensation was calculated for each of the 298 subjects. Energy compensation was calculated, as the negative value of the slope between the preload energy intake and the subsequent energy intake the study day after the preload consumption[1] (see Figure 1 in Chapter 1). The energy compensation values for the study of Chapter 2 were calculated with 10 pairs of preload energy intake values with subsequent energy intake values of that day. Energy compensation in Chapters 3 & 4, and in Chapters 5 & 6 were calculated with respectively, 9 and 6 pairs of preload energy intake with the subsequent energy intake of that day. For the studies of Chapter 7 the energy compensation was calculated between the two preload levels (3.1 and 5.0 MJ) and the energy intake of that day without the preload energy, for all 24 study days.

The mean energy compensation of 14% after the energy manipulations in the preloads was statistically significantly different from zero (95% CI, [5 to 23%]). This value is similar to the median value of 13%. However, this means that about 85% is not compensated for by the present subjects, and the subjects consumed less energy and fat per day when the low-energy products were consumed compared to the high-energy products. Both men and women showed low energy compensation values with 18% for men (95% CI, 3 to 34%) and 10% for women (95% CI, -1 to 22%). The meta-analysis shows a large variability in energy compensation values, with individual energy compensation values ranging from -262% to 328%. This implies that relatively large numbers of subjects are needed to find significant energy compensation after an energy manipulation.

The men and women of the present studies did not regulate their food intake within a day, nor within 12 days. This suggests that there is not a fine tuned mechanism controlling the short term and weekly food intake in normal weight humans.

Power calculations for energy intake

The present studies showed small differences in mean energy intake after the different treatments. It could be that the numbers of subjects were too small to find differences, because of the high within subject variability for energy intake. In Table 2 the number of subjects are calculated[2] for three different power levels (0.80, 0.90, 0.95) and three levels of differences for the effects of the treatments regarded as important (0.42 MJ (100 kcal), 0.84 MJ (200 kcal), and 1.67 MJ (400 kcal)). The results from Table 2 show that the number of subjects used in the present studies were large enough to have a high chance to find complete energy compensation if complete energy compensation would have occurred.

Macronutrient compensation

Macronutrient compensation occurred in none of the present studies, which is also found in many other studies[3-5]. This means that the subjects did not specifically adjust the intake of any macronutrient after preloads with different macronutrient contents. Apparently the subjects continued to consume their habitual diets with the normal meal composition. This observation implies that even when complete energy compensation would occur after replacement of fat by a fatreplacer, still the percentage energy derived from fat in the total diet would be reduced. This reduction of relative fat intake would be in line with the health recommendations and could improve health in the long run. It should be mentioned that when instead of a fatreplacer a carbohydrate replacer is used, the percentage energy derived from fat will increase in both the situation of no and complete compensation.

Table 2. Calculations of the sample sizes (n) under different conditions in a one-tailed 5% test of significance with a method described by Snedecor & Cochran[2].

	δ=0.42 MJ*	δ=0.84 MJ*	δ=1.67 MJ*
Men (σ=2.50 MJ)†			
Level of Power			
0.80	224	57	16
0.90	307	79	22
0.95	385	98	27
Women (σ=1.96 MJ)†			
Level of Power			
0.80	138	36	11
0.90	190	49	14
0.95	238	61	17

* δ represents the size of difference between the true effects of the treatments regarded as important.

† σ represents the mean within subjects standard deviation for the energy intake the day after the study day (day 2; see Table 1).

FEELINGS OF APPETITE

When consuming low-fat/energy products hunger feelings might increase, when compared to the normal-fat products. This increase in hunger may result in higher energy intakes. Therefore it is important to determine the effects of different foods on subjective feelings of appetite. There are many food properties that can influence feelings of hunger and satiety, such as the weight, volume, energy content, macronutrient composition, and physical state. In food products these properties are often directly related to each other, and therefore it is difficult to disentangle the different effects on feelings of appetite. Figure 1 gives a systematic overview of how the different properties mentioned above have an effect on feelings of hunger (satiety) and satiation in relation to each other. Changes in the amounts of macronutrients, dietary fibre or water can directly influence the satiation or satiety. However these changes can also act via energy level, weight/volume, structure or a combination of these three factors.

There are also other factors that can influence feelings of appetite like the weather, or the smell or pleasantness of foods. In Figure 1 the feelings of satiety and satiation influence the food intake. A priori the food intake is logically related to the feelings of appetite, as hunger and satiety are terms always used in connection with food intake.

The studies in the present thesis showed relevant effects on appetite feelings when the preloads were artificial unidentifiable formula foods (Chapter 2 and 3) but not when the energy differences were obtained with real foods (Chapter 4,5,6 and 7). It is remarkable that such large energy differences between preloads, ranging from 0.8 MJ to 1.9 MJ (see Table 1 Chapter 1), in the studies of Chapter 4, 5, 6 and 7, resulted in no or small differences in appetite. It could be that with usual foods the subjects can imagine what such a meal would mean for their satiety, which was not possible with the liquid and solid unidentifiable artificial preloads served as breakfast in milk shake beakers (Chapter 2 and 3).

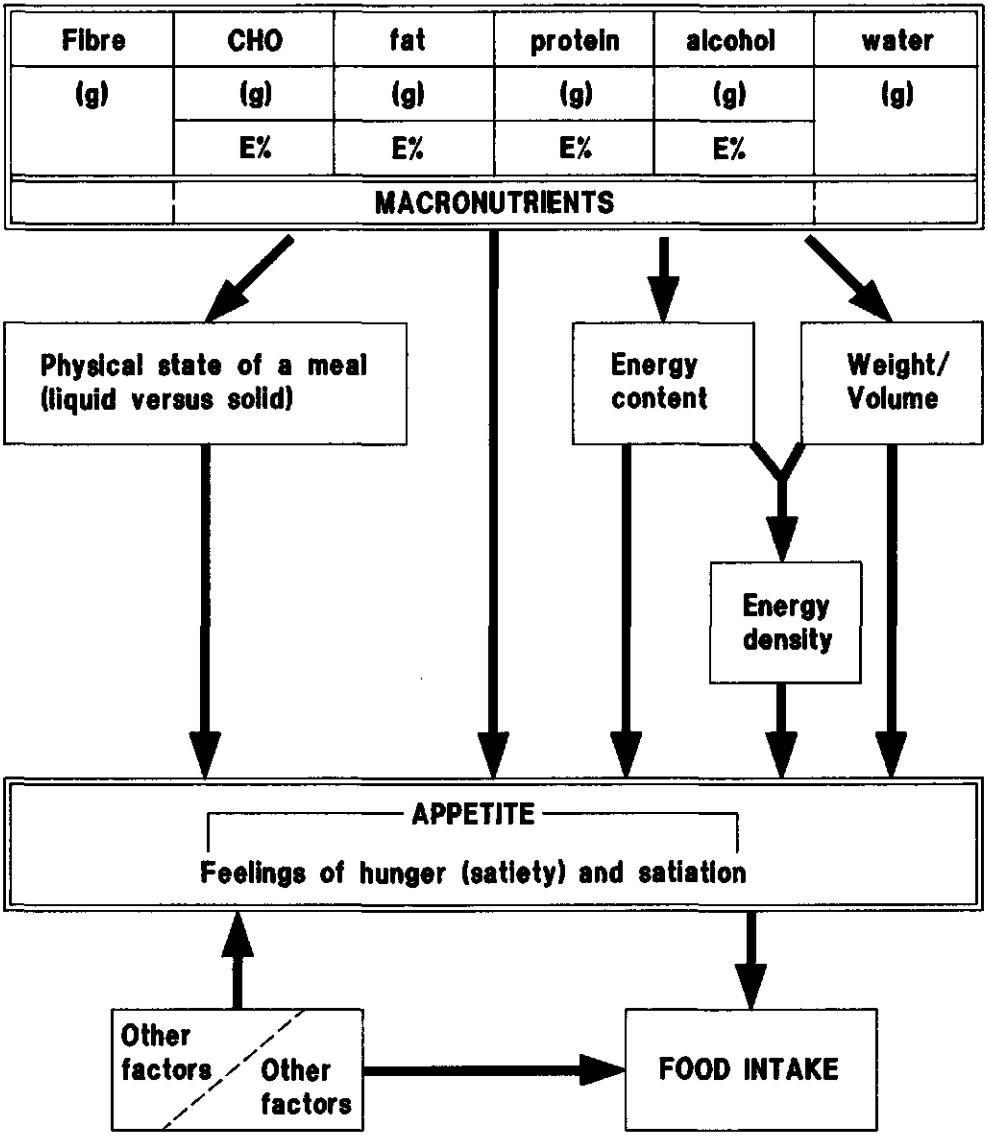

Figure 1. A systematic overview of how changes in meal or food composition might alter the feelings of appetite.
E% = energy percentage, CHO = carbohydrates.

SOME METHODOLOGICAL ISSUES IN APPETITE RESEARCH

There are many other factors, besides the energy content of a food, that can influence the subsequent energy intake and appetite feelings in man[6]. In this paragraph the factors that might influence the outcomes of appetite research are discussed.

Subjects characteristics

The subjects in the present studies were young, nonobese, non dieting men and women without eating disorders. The subjects were recruited at the Wageningen Agricultural University by posters and leaflets. This implies, that the subjects who participated were interested in participating. Ninety-five percent of the subjects that started with the experiments completed the experiment in the proper way, so it can be expected that there was not a selection bias by drop outs. The question arises to what extent the results of the present studies can be extrapolated to other groups of people?

Table 3. Subjects characteristics divided per degree of energy compensation.

Subjects Characteristics	Degree of energy compensation <0%	0%-50%	50-100%	>100%
number of subjects	124	82	55	37
% of total subjects	42%	28%	18%	12%
age (years)	21.5	22.3	21.9	21.2
height (cm)	175.8	176.0	177.1	177.3
weight (kg)	66.6	66.9	66.4	66.4
B.M.I. (kg/m2)	21.5	21.5	21.1	21.1
Restraint score (DEBQ)*	2.11	2.18	2.23	1.98
Energy compensation (%)	-58	22	73	148
Energy intake day 1 (MJ)†	8.91	8.49	8.94	9.59

* Dutch Eating Behaviour Questionnaire by Van Strien [30]

† Energy intake on the study day without the preload energy

Table 4. Pearson correlation coefficients between subject characteristics and energy compensation and energy intake (without preload intake) of the study day for all subjects (n = 298) and for men (n = 121) and women (n = 177).

	Energy compensation (%)	Energy-intake* day 1 (- PL) (MJ)
Men and women (n = 298)		
Age (years)	0.00 p = 0.94	0.01 p = 0.85
Height (cm)	0.04 p = 0.52	0.56 p < 0.0001
Weight (kg)	0.01 p = 0.93	0.45 p < 0.0001
B.M.I. (kg/m²)	-0.04 p = 0.50	0.01 p = 0.90
Restraint score	-0.02 p = 0.79	-0.36 p < 0.0001
Men (n = 121)		
Age (years)	-0.08 p = 0.38	-0.02 p = 0.83
Height (cm)	-0.14 p = 0.14	0.34 p < 0.0001
Weight (kg)	-0.05 p = 0.58	0.29 p = 0.002
B.M.I. (kg/m²)	0.04 p = 0.68	0.08 p = 0.39
Restraint score	-0.00 p = 0.98	0.06 p = 0.52
Women (n = 177)		
Age (years)	0.06 p = 0.44	-0.04 p = 0.61
Height (cm)	0.11 p = 0.13	0.23 p = 0.002
Weight (kg)	-0.00 p = 0.98	0.11 p = 0.16
B.M.I. (kg/m²)	-0.10 p = 0.20	-0.06 p = 0.40
Restraint score	0.02 p = 0.75	-0.12 p = 0.11

* The energy intake of the study day without the preload energy level (-PL).

It might be that differences in certain subjects characteristics within the present studies resulted in different outcomes on energy compensation. To investigate this, the 298 subjects were divided in four groups with different levels of energy compensation. Table 3 show the subjects characteristics for the people who compensated negatively, or compensated between 0 and 50%, or compensated between 50 and 100%, and subjects who compensated more than 100%. Of all the 298 subjects, 58% (55% of the women and 64% of the men) showed positive energy compensation values. There were no clear differences between the four groups and their subjects characteristics, this was also found when the men and women were analyzed separately. The level of energy compensation was independent of their body mass index (B.M.I.) and dietary restraint score. The amount of energy intake on the study days, without the preload energy values, also did not differ between the four groups.

Table 4 show the correlation coefficients between the subjects characteristics and the subjects' level of energy compensation and their energy intake levels (without preload energy). No relation was found between the level of energy compensation and the B.M.I. for normal weight subjects (the B.M.I. ranged between 16.4 and 28.4 kg/m^2). It is frequently mentioned that dietary restraint would influence food intake regulation[7-9]. In the present study, very high restraint subjects were not allowed to participate in the studies. For the subjects of this thesis there was no indication that energy compensation was influenced by restraint score. Significant positive correlations between the energy intake on the study day (without preload energy) with height were found in men and women, with higher intakes for taller subjects. This was also the case with the weight of the men. The B.M.I. in the present studies, however, did not correlate with the energy intake. Although the absolute mean energy intake between men and women is different, no large differences were found in regulation of food intake between men and women. There is no evidence that the present findings will be different for other normal weight healthy men and women.

The effects of pleasantness

Pleasantness is one of the possible confounders that can influence both the energy intake and feelings of appetite. In some of our studies substantial differences in pleasantness were found between the different preloads,and the question arises whether the pleasantness differences could have affected the results. With respect to the effects of pleasantness it is important to distinguish between the effects of different foods on satiety and the effects on satiation. We have the view that the satiation (i.e. the process that makes people terminate their meal) is strongly influenced by differences in pleasantness (e.g. people stop earlier with eating when the food tastes bad compared to food with a good taste). Hill et al.[10] found lower hunger ratings during the meal of unpleasant food compared to a meal of pleasant food. With respect to the satiety process it is not expected that the differences in pleasantness during a meal would strongly influence the subsequent energy intake and appetite ratings. In the present studies the effects of foods on satiety (and not satiation) were investigated. We think that differences in pleasantness have much less effects on the outcomes of satiety. In the same study of Hill et al.[10] as mentioned above, no effects were found for appetite feelings up to one hour after the two meals with different pleasantness. In a study of Warwick et al.[11] it was found that a tasty version of iso-caloric artificial breakfasts decreased hunger more, compared to the bland version. However they found higher carbohydrate intake in a testmeal after the bland breakfasts. In the studies of Chapter 6 we had 3 preloads with different palatability but with equal energy levels (these were the meal with 50 g water added, the meal with 25 g water and 25 g SPE added, and the meal with 50 g SPE added). The differences in palatability did not result in different outcomes with respect to subsequent appetite feelings and energy intake. At the moment, the question to what extent the pleasantness affects appetite after having eaten a meal is not answered.

Relative versus absolute appetite ratings

Feelings of appetite can be presented in absolute and relative values. When using relative appetite ratings, then the rating just before preload consumption is set to zero and the subsequent ratings are shown as the difference with the pre-preload rating. An argument in favour for the use of relative values is, that the time of pre-preload rating is the only time at which all subjects are in a similar state. Therefore the pre-preload rating can be used as a point of reference. There are however some disadvantages of using relative ratings. The most important issue is that random differences in the first rating affects all subsequent ratings. This implies that the pre-preload rating has an unjustified large weight on the outcome of the statistical analysis of the relative appetite ratings. These problems can be avoided by using absolute appetite ratings.

Comparing the time curves of appetite ratings becomes difficult when there are several different preloads. The use of the area under the appetite curve as a percentage of the maximum area (AUC%), can simplify this comparison as it provides only 1 value instead of a curve. The advantages and disadvantages of the AUC% are discussed in the analysis part of Chapter 3. With the AUC% it is possible to compare results of appetite feelings between different studies with the same or smaller deprivation periods.

The effects of knowledge of the experimental manipulation

In most experiments in which the effects of manipulated foods on subsequent dietary intake and appetite feelings were investigated, the subjects were unaware of the experimental manipulation. In normal life however, almost everyone is aware whether they buy and consume low-energy (low-fat) or normal products. The effects of knowledge on subsequent food intake is often investigated by giving subjects true and false information.[9,12-15] If differences occur in subsequent energy intake after preload consumption with equal energy levels, then the effect of knowledge is supposed to be strong. In some studies strong effects of knowledge were found[12,13], whereas in others no effects were found[9,14,15].

The results from the studies from Chapter 7 where we compared no information with the true energy content information, showed that normal weight women showed no differences in energy compensation. For men information seemed to result in partial energy compensation which was not found in uninformed men. However, the informed men compensated for less than half of the energy difference between the fat- and SPE-treatment. It seems that a relative large difference in energy content of the preloads did not result in large energy intake differences in normal weight subject.

Short versus long term investigations

Appetite research is often short term research. In the present thesis also short term studies (1 day) were presented in Chapters 2 to 6, and longer term studies (12 days) in Chapter 7. Short term studies can give an indication of the within day food intake regulation. However in short term experiments subjects receive each preload once, and it is not necessary that similar results will be found after repeated exposures.

Louis-Sylvestre et al.[16] found that adolescent males did not compensate at dinner for an 0.84 MJ (200 kcal) difference in an afternoon snack after the first exposure. However, precise energy compensation was reported after repeated exposure, suggesting caloric adjustment of human intake. Longer term studies can give information about the weekly or monthly food intake regulation. The longer the time period of investigation, the better the extrapolation to normal life situations is.

Plus vs minus manipulation

There have been some studies[17,18] that suggested that when more energy is consumed in a meal compared to the habitual amount, no energy compensation occurs, whereas when less energy is consumed in a meal compared to the habitual amount, precise energy compensation occurs. The background for this phenomenon could be of evolutionary origin. In pre-history gathering food was a hard task, and shortage of food threatened man's lives. An abundance of food was never a health problem, like it is nowadays. It might be that metabolism of man developed in such a way that a negative energy balance is easier "detected" than a positive energy balance. Although in some of the present studies the plus-minus theory seemed to be supported, the meta-analysis did not confirm this, because no correlation between height or weight and the level of energy compensation was found (see Table 3).

THE FATREPLACER SUCROSE POLYESTER (SPE)

SPE and nutritional status

In this thesis, SPE was studied within the context of food intake control. Originally SPEs were developed as cholesterol lowering substances[19]. Due to the lipophilic character of SPE, and because it remains in the gut, a higher percentage of the lipophilic cholesterol remained in the oily phase in the gut and less was absorbed from the gut[20-25]. This is however not a specific action with respect to cholesterol but generally with respect to all lipophilic substances like fat soluble vitamins[22-25] and medicines or oral contraceptives[26]. Therefore, special attention needs to be paid to the effects of SPEs on the nutritional status of humans, especially to the absorption and status of fat soluble vitamins and other fat-soluble substances.

An other phenomenon that coincides with the consumption of SPE is that the consistency of the stools becomes softer. In some cases the unwanted situation of anal leakage of SPE-oil can occur, but this can be resolved by making an SPE with fatty acids that have a higher melting point. In our studies no such effects of SPE were mentioned by the subjects in the short term (1 day) studies, but a significantly higher frequency of defecation and gastro-intestinal complaints were found after repeated (12 days) consumption of 50 g SPE..

SPE and weight control

The longer-term effects of energy and fat manipulations on the control of food intake have been investigated in several studies[27-29] varying from five-day[29] to seventy-seven-day[27] periods. In all these studies subjects consumed less fat/energy when consuming low-fat product and consumed more fat/energy when consuming high-fat products. These studies and our studies with SPE show that SPE might help people to reduce the fat and energy intake in their diet.

Whether the replacement of fat by SPE can help in reducing the body weight of obese people is not clear. Glueck et al.[23] found in 10 obese that a decrease of 2.0 MJ energy intake per day on an SPE-diet compared to a fat-diet resulted in a non-significant decrease of only 0.47 kg in a 20 day period. Mellies et al.[25] found no differences in weight loss between a placebo condition and a condition where 27 g of fat was replaced by SPE in a cross sectional study with 13 and 11 obese subjects respectively. Our studies on the other hand show a significant mean weight difference of 0.4 kg at the end of the 12 day period between the fat- and the SPE-treatment.

CONCLUSIONS

The present studies show that the replacement of fat by a fat-replacer can help to reduce the daily energy and fat intake in the diet when compared to the normal dietary energy and fat intake. The reduced fat intake is in line with the present nutrition and public health recommendations. The use of non-absorbable fat-replacers can also help in managing weight control. The substitution of dietary fat in food products by a non-absorbable fat-replacer such as SPE, has no or little effect on the satiating power of these products. However, at the moment the market introduction of SPE in food products is further subject to critical evaluation on other health aspects, especially in the long term.

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SUMMARY

Fat-replacers are ingredients/substances that can substitute, partly or completely, the dietary fat of normal food products, preferably without altering the sensory and physical properties of the food. Substitution of fat by a fat-replacer results in decreased levels of fat and energy in food products. Low-fat/energy products can help decreasing the dietary fat and energy intake, and assist with body weight regulation.

The main objective of the eight studies presented in this thesis, was to investigate the effects of consumption of meals with different amounts of fat/energy on subsequent dietary intake and feelings of hunger and satiety. In six of the eight studies of this thesis, the non-absorbable fat-replacer sucrose polyester (SPE) was used as a tool to reduce the fat and energy content of foods. As the outcomes of studies on human food intake may depend on the specific methodology that is used, some methodological issues are also evaluated in this thesis.

Sucrose polyester (SPE) has a similar appearance, and the same physical and sensory properties as normal dietary fat, but is not digested and absorbed in the human body. SPEs are synthesized by esterification of sucrose with medium- and long-chain fatty acids.

In Chapter 2 the short term (1 day) effects of different energy levels (0.42, 1.05, and 1.67 MJ) and different macronutrients (protein, fat, and carbohydrate) on subsequent food intake and feelings of appetite were investigated. Subjects received liquid artificial (i.e. unidentifiable formula foods) preloads as breakfast. It was found that neither the energy content nor the macronutrient composition of the liquid artificial breakfasts had any effect on the energy and macronutrient intake during lunch and the remainder of the day. Lower hunger ratings were found after higher energy levels of the preloads. No differences in appetite feelings were found between the three macronutrients, which suggests that fat is equally satiating per joule as are protein and carbohydrate.

The short term (1 day) satiating effects of energy levels (0.42, 1.67, and 3.35 MJ) and physical state (liquid; solid by gum, solid by gelatin) were investigated in the study described in Chapter 3 with artificial unidentifiable preloads as breakfast. The energy levels were altered by adding fat to the preloads. Higher energy intakes at lunch were found after the low energy preloads compared to the high energy preloads. However, for the energy intake of the entire day no

differences were found after the different energy levels or the different physical states. Large differences were found for appetite feelings for both the energy levels and the physical state of the preloads. Higher energy levels and solid preloads resulted in less hunger compared to lower energy levels and liquid preloads.

In the next two chapters the short term (1 day) satiating effects of croissants consumed at lunch time were investigated. In Chapter 4 three different energy levels (1.66, 2.53, and 3.39 MJ) were investigated at three times of the day (breakfast, lunch, and during the afternoon). This was the first study in which the fat-replacer SPE was used to manipulate the energy levels of the preloads. No differences in energy intake or feelings of appetite were found after the different preloads. In Chapter 5 the satiating effects of a high-fat (3.45 MJ) versus a low-fat/high-SPE croissant (1.80 MJ) were investigated, each followed by three different deprivation periods (0:15, 2:15, and 4:45 h). No effects were found of the preload energy levels on the energy intake and the feelings of appetite. The 4:45 h deprivation period resulted in lower energy intakes and more hunger compared to the 0:15 and 2:15 h deprivation periods.

In Chapter 6 the short term satiating effects of different amounts of fat and SPE (1.8, 2.7 and 3.7 MJ) in warm meals at lunch time were investigated in two studies that were replicates of each other. In the first study the warm meals consisted of rice, in the second study of macaroni. Two hours after the consumption of the warm meals a test-meal buffet was presented to the subjects of which they could eat as much as they liked. For women no differences in energy intake or appetite feelings were found after the different energy levels of the warm luncheon meals. The men of the rice study showed no compensation for the energy differences between the manipulated meals. Whereas for the men of the macaroni study partial energy compensation occurred (46%), which was mainly due to compensation at the test-meal buffet. For men of both studies hunger ratings were lower after the meals with the higher energy content.

To investigate whether the short term findings could be extrapolated to longer term periods, we investigated the longer-term (12 days) effects of fat and SPE consumption on food intake and body weight in 2 studies (Chapter 7). In the first study, the subjects received no information about the experimental manipulations, as was the case in all our short-term studies. In the second study, the subjects were told daily, whether they received a "normal" (5.0 MJ) three course meal or a 3.1 MJ meal where 52 g of fat was replaced by 52 g of SPE. For women no energy compensation was found in either study. For the uninformed men no energy compensation was found either, but for the informed men significant energy compensation was found (46%). This value decreased to 29%

when two days with excessive alcohol intake during the SPE-treatment, due to celebrations, were left out. Although this value was still significantly different from zero, it was far from complete energy compensation, with as a result that the total daily energy intake was lower during the SPE period. This was accompanied by equivalent changes in body weight. No large differences were found for appetite ratings in either group.

A meta-analysis on energy compensation for all eight studies of the above mentioned chapters is presented in Chapter 8. For the entire population of the eight studies (n = 298), 14% energy compensation was found, and no differences between men and women. There was no evidence that differences in subject characteristics resulted in different levels of energy compensation.

In none of the studies macronutrient specific compensation was found. This means that the subjects did not consume more fat after a low-fat meal, but consumed foods with the habitual macronutrient composition. The consumption of a fat-replacer instead of dietary fat will therefore decrease the total fat intake, independent of the degree of energy compensation. With respect to appetite feelings it seemed that energy differences in artificial unidentifiable products were better monitored than energy differences in normal food products. Low-energy artificial preloads were followed by more hunger compared to high-energy artificial preloads. These differences in appetite feelings were not found for normal food products.

It is concluded that normal weight, non dietary restraint, men and women do not or poorly recognize covert energy differences between meals, and poorly adjust their food intake of subsequent meals after both covert and overt energy manipulations. Therefore the replacement of fat by a non-absorbable fat-replacer such as SPE can help to reduce both the daily energy and fat intake in normal weight humans. These effects, however, do not imply that SPE should be part of the daily food supply. Other effects e.g. on micronutrient absorption and status should also be considered.

SAMENVATTING

Vetvervangers zijn stoffen die het voedingsvet in normale voedingsmiddelen geheel of gedeeltelijk vervangen, bij voorkeur zonder de sensorische en fysische eigenschappen van het voedingsmiddel te veranderen. Het gebruik van vetvervangers heeft tot gevolg dat de hoeveelheid vet en energie van voedingsmiddelen vermindert. Laag-vet en laag-energetische produkten kunnen de vet- en energie-inneming van mensen helpen verlagen en daardoor een bijdrage leveren aan de regulatie van het lichaamsgewicht.

In dit proefschrift is beschreven wat de effecten zijn van verschillende hoeveelheden vet/energie in voedingsmiddelen/maaltijden op de daarop volgende voedselinneming en eetlustgevoelens bij jonge mensen zonder overgewicht. Het niet absorbeerbare vet sucrose polyester (SPE) is in zes van de acht studies gebruikt als middel om de vet/energie-inhoud van voedingsmiddelen/maaltijden te verminderen. In ieder experiment is een vaste hoeveelheid van een gemanipuleerde maaltijd verstrekt, gevolgd door een periode waarin de deelnemers niet mochten eten. Na deze periode konden de vrijwilligers hun normale eetpatroon vervolgen. De deelnemers werden niet geïnformeerd wanneer ze welke manipulatie kregen. De resultaten van deze experimenten kunnen beïnvloed zijn door de gebruikte methodologie, daarom zijn ook enige methodologische aspecten onderzocht.

De vetvervanger SPE lijkt qua uiterlijk op vet en heeft dezelfde fysieke en sensorische eigenschappen als voedingsvet, maar het wordt niet verteerd en geabsorbeerd in het menselijk lichaam. SPE wordt gemaakt door esterificatie van sucrose met vetzuren.

In Hoofdstuk 2 zijn de korte termijn effecten (1 dag) onderzocht van kunstmatige produkten met verschillende hoeveelheden energie (0.42, 1.05, 1.67 MJ) en een verschillende macronutriëntensamenstelling (eiwit, koolhydraat en vet) op de voedselinneming en gevoelens van eetlust. De vrijwilligers kregen een soort milkshake als ontbijt. De deelnemers rapporteerden sterkere hongergevoelens na de laag-energetische milkshakes vergeleken met de hoog-energetische milkshakes. Vet, koolhydraat en eiwit werkten even verzadigend per energie-eenheid. Er is geen verschillend effect gevonden op de energie- of macronutriënteninneming tussen de verschillende ontbijten.

De korte termijn effecten (1 dag) van energieniveaus (0.42, 1.67, 3.35 MJ) en de fysieke toestand van voedingsmiddelen, vast versus vloeibaar, op energie-inneming en eetlustgevoelens zijn onderzocht in Hoofdstuk 3. Ook in deze studie consumeerden de vrijwilligers kunstmatige ontbijten. Het energieniveau werd gemanipuleerd door toevoeging van verschillende hoeveelheden vet. Grote verschillen in eetlustgevoelens werden er gevonden na consumptie van de verschillende ontbijten. De hoog-energetische ontbijten waren meer verzadigend dan de laag-energetische ontbijten en de vaste ontbijten waren meer verzadigend dan de vloeibare ontbijten. Na een laag-energetisch ontbijt consumeerden de vrijwilligers meer energie tijdens de lunch, vergeleken met een hoog-energetisch ontbijt. De energie-inneming over de gehele dag was echter niet verschillend. Verschillen in fysieke toestand van het ontbijt resulteerden niet in verschillen in energie-inneming.

In Hoofdstuk 4 en Hoofdstuk 5 zijn de korte termijn effecten (1 dag) onderzocht van gemanipuleerde croissants met verschillende hoeveelheden vet en SPE op de eetlustgevoelens en voedselinneming. In Hoofdstuk 4 zijn de effecten van drie energieniveaus (1.66, 2.53, 3.39 MJ) onderzocht op drie verschillende momenten van de dag; ontbijt, lunch, in de loop van de middag. Dit was de eerste studie in dit proefschrift waarbij de vetvervanger SPE is gebruikt om de energieniveaus te manipuleren. De consumptie van croissants met de verschillende energieniveaus leidde niet tot verschillen in gevoelens van eetlust en energie-inneming. In Hoofdstuk 5 zijn croissants met veel vet (3.45 MJ) vergeleken met croissants waarin vet was vervangen door SPE (1.80 MJ). Ook in deze studie zijn geen verschillen gevonden in eetlustgevoelens en energie-inneming na de consumptie van de croissants met twee verschillende energieniveaus.

De korte termijn (1 dag) effecten op energie-inneming en eetlustgevoelens van gemanipuleerde warme lunches zijn onderzocht in twee studies beschreven in Hoofdstuk 6. In deze studies werden vet en SPE gebruikt om de energieniveaus van de maaltijden te veranderen (1.8, 2.7, 3.7 MJ). Als basis voor de warme lunch werd in de eerste studie een nasi-maaltijd en in de tweede studie een macaroni-maaltijd gebruikt. Twee uur na de consumptie van de lunch kregen de vrijwilligers een buffet aangeboden waarvan ze zoveel mochten eten als ze wilden. In zowel de nasi- als macaroni-studie hadden de mannen minder honger na de lunches die meer energie bevatten. Voor de vrouwen werden geen verschillen gevonden in eetlustgevoelens en energie-inneming na de verschillende lunches. De mannen van de nasi-studie compenseerden niet voor de energieverschillen tussen de lunches, terwijl de mannen van de macaroni studie een gedeeltelijke energetische compensatie vertoonden van 46%, die voornamelijk werd veroorzaakt door compensatie tijdens het buffet.

In Hoofdstuk 7 hebben we in twee studies de langere termijn (12 dagen) effecten onderzocht van vet en SPE op eetlustgevoelens, de voedselinneming en het lichaamsgewicht. In de eerste studie werden de deelnemers niet geïnformeerd of hun 3-gangen diner SPE bevatte. In de tweede studie werden de vrijwilligers dagelijks verteld of ze een "normaal" diner kregen (5.0 MJ) of een diner kregen waar 52 gram vet was vervangen door SPE (3.1 MJ). Er werd geen energetische compensatie gevonden voor de vrouwen van beide studies en voor de mannen die geen informatie kregen omtrent de samenstelling van hun diner. Voor de geïnformeerde mannen werd een energetische compensatie gevonden van 46%. De energetische compensatie is verre van compleet, wat als gevolg heeft dat de deelnemers een verlaagde energie- en vetinneming gedurende de SPE-periode hadden. De verschillen in energie-inneming als gevolg van de verschillen in energie-inhoud van de diners met SPE en vet ging samen met veranderingen in het lichaamsgewicht. Wat betreft eetlustgevoelens zijn geen grote verschillen gevonden tussen de twee condities.

Van de acht studies die hierboven zijn beschreven is in Hoofdstuk 8 een meta-analyse uitgevoerd met energetische compensatie als belangrijkste component. Wanneer de resultaten van alle vrijwilligers van de acht studies samen worden genomen (n = 298) dan was de gemiddelde energetische compensatie 14%. Verschillen in de karakteristieken van de vrijwilligers, zoals lichaamsgewicht, lengte en lijngericht gedrag, konden de mate van gevonden energetische compensatie niet verklaren.

In geen van de studies is een macronutriëntspecifieke compensatie gevonden. Dit betekent dat de vrijwilligers bijvoorbeeld niet meer vet consumeerden na een laag-vet maaltijd vergeleken met een hoog-vet maaltijd. Na iedere gemanipuleerde maaltijd, consumeerden de proefpersonen de rest van de dag een voeding die qua macronutriëntensamenstelling overeen kwam met de gebruikelijke samenstelling van hun voeding. Dit heeft als consequentie dat onafhankelijk van de mate van energetische compensatie, de vetinneming altijd vermindert bij het gebruik van een niet absorbeerbare vetvervanger zoals SPE. Met betrekking tot gevoelens van eetlust, lijkt het erop dat de vrijwilligers beter reageerden op energiemanipulaties in onbekende kunstmatige produkten vergeleken met bekende produkten. Na laag-energetische kunstmatige produkten werd meer honger gerapporteerd dan na hoog-energetische produkten, maar deze verschillen werden niet gevonden voor energieverschillen bij normale voedingsmiddelen.

Wij concluderen dat gezonde vrijwilligers met een normaal lichaamsgewicht niet of nauwelijks reageerden op verschillen in energie-inhoud van voedingsmiddelen, hetgeen tot uiting kwam in geen of kleine verschillen in eetlustgevoelens en energie-inneming. Dit gold zowel voor de ongeïnformeerde als de geïnformeerde vrijwilliger en voor de korte als langere termijn. Het gebruik van een niet absorbeerbare vetvervanger zoals SPE kan mensen met een normaal gewicht helpen om de vet- en energie-inneming te verlagen. Deze effecten alleen, betekenen niet dat SPE een normaal bestanddeel van onze voeding kan worden. Andere effecten, zoals de micronutrientenabsorptie en maag-darm klachten, moeten ook in ogenschouw worden genomen.

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Toine Hulshof
Wageningen, oktober 1994

CURRICULUM VITAE

Toine Hulshof werd geboren op 20 augustus 1966 te Gendt. Van 1978 tot 1984 volgde hij zijn middelbare school opleiding (VWO) aan de Scholengemeenschap "Oost Betuwe" te Bemmel. In Augustus 1984 begon hij met de studie Voeding van de Mens aan de toenmalige Landbouwhogeschool te Wageningen. Van februari tot juli 1989 liep hij stage bij het Fysiologisch Instituut van de Universiteit van Lausanne te Zwitserland. In maart 1990 behaalde hij de titel van landbouwkundig ingenieur in de afstudeerrichting Voeding van de Mens met als afstudeervakken Voedingsleer en Statistiek.

Het in dit proefschrift beschreven onderzoek werd uitgevoerd van april 1990 tot april 1994 aan de vakgroep Humane Voeding van de Landbouwuniverstiteit Wageningen, waar hij als Assistent in Opleiding (AIO) was aangesteld. Hij maakte deel uit van het Postgraduate Programme in Human Nutrition. In juni en juli 1991 was hij op werkbezoek bij het Biopsychologisch Instituut van Dr Blundell van de Universtiteit van Leeds te Engeland. In februari en maart 1994 heeft hij zijn onderzoek gepresenteerd en besproken bij acht instituten en universtiteiten aan de oostkust van de Verenigde Staten van Amerika, die onderzoek verrichten op het gebied van de regulatie van de voedselinneming.