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ORIGINAL CONTRIBUTION

Effects of high and normal soyprotein breakfasts on satiety and subsequent energy intake, including amino acid and 'satiety' hormone responses

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Abstract *Background* The role of dietary protein in short term satiety is of interest with respect to body weight regulation. *Aim* To compare the effects of a high versus a normal soyprotein breakfast on satiety and subsequent energy intake (EI), including 'satiety' hormones and plasma amino acid responses. *Methods* Twenty-five healthy subjects (mean ± SEM, BMI: 23.9 ± 0.3 kg/m^2; age: 22 ± 1 years) received a subject-specific standardized breakfast: a custard with soy as single protein type with either 10/55/35 (normal-protein) or 25/55/20 (high-protein) En% protein/carbohydrate/fat in a randomized, single-blind design. Appetite profile (Visual Analogue Scale, VAS), plasma glucose, insulin, Glucagon-like Peptide 1, ghrelin, and amino acid concentrations were determined for 4 h, determining the sensitive time point to assess EI. Since at 180 min glucose and insulin concentrations still were significantly different, in a second set of experiments subjects received an ad lib lunch at 180 min after the breakfasts; EI was assessed. *Results* Overall the 25 En% soy-custard was rated as being more satiating than the 10 En% soy-custard ($P < 0.01$) and there was a difference at 20 min after breakfast (64 ± 5 vs. 52 ± 5 mmVAS, $P < 0.05$), related to higher postprandial taurine concentrations ($P < 0.05$). Insulin response was increased more after the 25 En% than after the 10 En% soy-custard (AUC: 7,520 ± 929 vs. 4,936 ± 468 mU/l h, $P < 0.001$). There was no difference in EI (25 En%: 3,212 ± 280 kJ vs. 10 En%: 3,098 ± 286 kJ, ns). *Conclusion* A high soyprotein breakfast is more satiating than a normal soyprotein breakfast related to elevated taurine and insulin concentrations.

Key words satiety – energy intake – soyprotein – taurine – insulin

Introduction

The increasing incidence of obesity is considered as a major health problem due to its co-morbidity of a number of diseases, including diabetes mellitus type 2, cardiovascular disease, and certain types of cancer [14, 15]. Obesity is the result of a positive energy balance due to energy intake (EI) exceeding energy expenditure. In the system of body weight regulation several pathways are involved and therefore weight management requires a multi-factorial approach [29].

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Recent findings suggest that a relatively elevated protein intake seems to play a role during weight loss as well as during weight maintenance thereafter [4, 12, 17, 28]. The importance of satiety in this respect appears from the study by Weigle et al. [28] where a high protein diet reduced ad lib food intake while sustaining satiety at a comfortable level during a 12-week period. In addition to the protein-induced satiety after a high protein diet, protein-induced satiety has also been shown after a single meal [3, 5, 7]. Previous studies have shown satiating effects of high versus normal protein meals with a mixture of habitually consumed proteins [7, 29]. Data on specific proteins in different concentrations affecting satiety are however limited and the question remains whether the larger satiating effects of high protein meals hold for each specific type of protein.

Soyprotein is considered as a complete protein. Its nutritional value is roughly equivalent to that of animal protein of high biological value [33]. A number of studies in animals and humans suggest that consumption of soyprotein has beneficial effects on lipid metabolism and obesity. Several lines of evidence show that soyprotein may favorably affect lipid absorption, insulin resistance, fatty acid metabolism and other hormonal, cellular, or molecular changes associated with adiposity. Soyprotein has also been suggested to decrease EI through increased satiety [27].

In order to answer the question whether the larger satiating effect of high protein meals also holds for soyprotein, we investigated possible differences in satiety between a high and normal amount of soyprotein and the mechanisms accompanying those differences. Since the timing of a test meal plays an important role [2], first the sensitive moment in time to offer a test meal was determined. Soyprotein was offered as a single protein source in a breakfast consisting of 20% of the subject-specific daily energy requirements, with amounts of soyprotein that represent the highest recommended protein intake per day, i.e. 25% of energy from protein versus the lowest (normal) protein intake per day, 10% of energy from protein [18]. Protein was exchanged with fat; carbohydrate content was kept constant at a level of 55 En% because of its effects on protein metabolism [13].

The aim of the study was to compare the effects of a high versus a normal amount of soyprotein containing breakfast on satiety and EI, including plasma amino acids (AA), glucose, insulin, Glucagon-like Peptide 1 (GLP-1) and ghrelin concentrations over a 4-h period. After having determined the sensitive moment in time, subjects received in a second set of experiments the same breakfasts and ad lib EI at lunch was determined at this time point.

Subjects and methods

Subjects

Thirty healthy male and female volunteers [Body Mass Index (BMI) 22–30 kg/m^2, age 18–40 years] were recruited by advertisements in local newspapers and on notice boards at the university. They underwent a screening including medical history, measurement of body weight and height and cognitive restrained eating using a Dutch translation of the Three Factor Eating Questionnaire (TFEQ) [22, 30]. Twenty-five subjects (11 males, 14 females) were selected on being in good health, non-smokers, non-vegetarian, not cognitively dietary restraint (TFEQ Factor 1 score ≤9), not using medication apart from oral contraceptives and at most moderate alcohol users (≤10 alcoholic consumptions per week). Their mean age was 22 ± 1 year, and their body weight was 74.4 ± 1.8 kg (BMI: 23.9 ± 0.3 kg/m^2). A written informed consent was obtained from these participants and the study protocol was approved by the Medical Ethical Committee of the Academic Hospital Maastricht.

Study design

A randomized, single blind, within-subject experimental study was performed. All subjects came to the university on two occasions, separated by at least 1 week. On each test day subjects received a subject-specific standardized breakfast and appetite ratings and blood parameters were obtained for 4 h after breakfast.

The sensitive moment in time to offer lunch was determined by the latest time point after breakfast where (part of) the measured parameters still were statistically significant. After 2 months, when the sensitive moment in time was determined, subjects again came to the university on two occasions in a randomized, single blind design, separated by at least 1 week. On each test day subjects received a subject-specific standardized breakfast and an ad lib lunch was offered at the pre-determined time point.

Breakfast

Breakfast was offered as a custard with soy (Supro® 590, The Solae Company, St. Louis, USA) as a single protein source, with either protein/carbohydrate/fat: 10/55/35 En% (normal protein) or protein/carbohydrate/fat: 25/55/20 En% (high protein). The breakfast contained 20% of daily energy requirements, calculated as basal metabolic rate (BMR), according to the equations of Harris-Benedict, multiplied by an activity index of 1.75 which is the average value reported

Table 1 Amino acid content of the breakfasts given as a custard with either 10 En% or 25 En% soyprotein content (g amino acids/100 g custard)

	Soy	
	10%	25%
Glutamic acid[a]	0.328	0.816
Aspartic acid[b]	0.200	0.497
Cysteine	0.022	0.054
Serine	0.089	0.220
Histidine	0.048	0.119
Glycine	0.071	0.177
Threonine	0.066	0.164
Arginine	0.139	0.345
Alanine	0.073	0.182
Tyrosine	0.069	0.171
Valine	0.085	0.212
Methionine	0.022	0.056
Isoleucine	0.089	0.222
Phenylalanine	0.094	0.234
Tryptophan	0.023	0.057
Leucine	0.145	0.360
Lysine	0.110	0.274
Proline	0.087	0.216

[a]Glutamic acid = glutamine + glutamate
[b]Aspartic acid = asparagine

for the general population in the Netherlands [8, 31]. The mean energy content of the breakfast was 2.52 ± 0.07 mJ and the provided breakfasts were completely finished within 15 min.

The custards were produced by NIZO Food Research bv. (Ede, The Netherlands) and had tapioca starch (Farinex VA50T, AVEBE, Veendam, The Netherlands and Perfectamyl 3108 AVEBE, Veendam, The Netherlands) and sunflower oil (Reddy, NV Vandemoortele, Roosendaal, The Netherlands) as the carbohydrate and fat sources and were citrus-vanilla (Citrus, J.B. de lange, Belfeld, The Netherlands; Vanilla, J.B. de lange, Belfeld, The Netherlands) flavored. Extensive product development and use of a taste panel lead to custards that did not differ significantly in color, taste, or viscosity. The amino acid composition of the custards is presented in Table 1.

Lunch

According to a normal Dutch lunch consisting of bread and a filling, lunch consisted of Turkish bread (400 g) with egg salad (400 g) with 13/41/46 En% protein/carbohydrate/fat with an energy density of 11.4 kJ/g. Beforehand it was tested whether all subjects liked the lunch sufficiently. Subjects were instructed to eat till they were comfortably full.

Study protocol

The protocol started at 08.00 h after an overnight fast from 22.00 h. A Venflon catheter was placed in a superficial dorsal vein of the hand for blood sampling. To obtain arterialized venous blood samples the hand was placed in a thermostatically controlled hot box at 60°C for 20 min before the sampling time. A basal blood sample was taken and appetite ratings were scored. After 5 min a second basal blood sample was obtained and breakfast was offered (t = 0 min) and completed within 20 min. After the first and the last bite, taste perception was scored. Appetite ratings were completed just before breakfast and at 20, 40, 60, 80, 100, 120, 180 and 240 min after breakfast.

Blood samples for urea and amino acid determination were obtained at −5 min and subsequently at the same time points as the appetite ratings; blood samples for determination of glucose, insulin, and ghrelin concentrations were obtained before and 40, 60, 120 and 180 min after breakfast. Venous blood samples for determination of GLP-1 concentration were obtained separately before, and at 30, 60, 90, 120 and 180 min after breakfast by means of a Venflon catheter placed in an antecubital vein [1]. Subjects were allowed to drink two glasses of water spread over the morning.

In the second set of experiments, the protocol started after an overnight fast from 22.00 h at 8.30 h with scoring appetite ratings. Breakfast was offered (t = 0 min) and completed within 20 min. Lunch was offered at the pre-determined time point of 180 min after breakfast (see "Results"). Subjects were allowed to drink three glasses of water spread over the entire test period.

Measurements

Appetite profile

To determine the appetite profile, hunger, fullness, satiety, and desire to eat were rated on 100 mm Visual Analogue Scales (VAS), anchored with 'not at all' and 'extremely' during the test day [21]. Subjects were instructed to rate themselves by marking the scale at the point that was most appropriate to their feeling at that time. The distance from this point to the left end of the scale was measured in mm; changes from baseline (Δ) were calculated by subtracting the baseline score (−5 min) from the score at a certain time point.

Taste perception

Taste perception profiles of the custards were assessed after the first and the last bite of the breakfast using 100 mmVAS, anchored with 'not at all' and 'extremely' on the aspects: pleasantness, sweetness, sourness, saltiness, bitterness, savouriness, crispiness and creaminess.

Energy intake

Lunch was weighed before and after eating and EI was calculated by multiplying the difference of the weight of the lunch by the energy value of the lunch as determined by the product labels (11.4 kJ/g).

Blood parameters

Blood was distributed into EDTA tubes for glucose, insulin, and ghrelin measurement. For GLP-1 measurement blood was collected in EDTA tubes with added dipeptidyl peptidase IV inhibitor. For amino acid and urea determination, blood was collected in lithium heparin tubes. Blood samples were centrifuged at 4°C for 10 min at 3,000 rpm. Hydrochloric acid and phenylmethylsulfonyl fluoride were added to plasma for active ghrelin determination. For amino acid analysis, 250 µl plasma was deproteinized by mixing it with 20 mg dry sulfosalicylic acid. For analysis of urea, 200 µl plasma was deproteinized by mixing it with 20 µl of a 500 g/l trichloroacetic acid solution. All samples were stored at −80°C until further analysis. Plasma glucose concentrations were determined using the hexokinase method (Glucose HK 125 kit, ABX diagnostics, Montpellier, France). Insulin concentrations were measured by RIA (Linco Research Inc., St. Charles, Missouri, USA). Plasma active ghrelin concentrations were measured by ELISA (Linco Research Inc., St. Charles, Missouri, USA). Plasma active GLP-1 samples were analyzed using ELISA (EGLP-35K; Linco Research Inc., St. Charles, Missouri, USA). Plasma concentrations of amino acids were determined with the use of a fully automated HPLC (Pharmacia, Woerden, The Netherlands), after precolumn derivatization with *o*-phthaldialdehyde [25]. Plasma urea was analyzed spectrophotometrically on a COBAS Mira S (Roche Diagnostica, Hoffman-La Roche, Basel, Switzerland).

Statistical analysis

Data are presented as mean changes from baseline ± standard error to the mean (SEM), unless otherwise indicated [16]. The area under the curve (AUC) of changes from baseline over time was calculated using the trapezoidal method. A repeated measures ANOVA was carried out to test for the effects of protein content and time and a protein content × time interaction effect on changes in satiety ratings and concentrations of glucose, insulin, ghrelin, GLP-1 and taurine over time. Furthermore, differences between the breakfasts were analyzed per time point. A repeated measures ANOVA was carried out to test for the effect of protein content on the AUC of satiety ratings and concentrations of glucose, insulin, ghrelin, GLP-1, amino acids and urea.

Regression analyses were performed to determine the relationships between the AUC of appetite ratings and the AUC of plasma glucose, insulin, ghrelin, and amino acid responses. Furthermore, regression analyses between the AUC of plasma glucose, insulin, and ghrelin and the AUC of plasma amino acids were performed.

After the second set of experiments, a repeated measures ANOVA was carried out to determine possible differences in EI between the breakfasts. A P-value < 0.05 was regarded as statistically significant. Statistical procedures were performed using StatView 5.0 (SAS Institute Inc., USA, 1998).

Results

Appetite profile

Baseline satiety ratings were not different between treatments. There was no protein content × time interaction effect (ns). Protein content ($P < 0.01$) and time ($P < 0.001$), however, both had an effect on satiety ratings (Fig. 1). Satiety ratings were more increased after a breakfast with 25% of energy from soyprotein than after a breakfast with 10% of energy from soyprotein ($P < 0.01$) and there were significant differences over time ($P < 0.001$, Fig. 1).

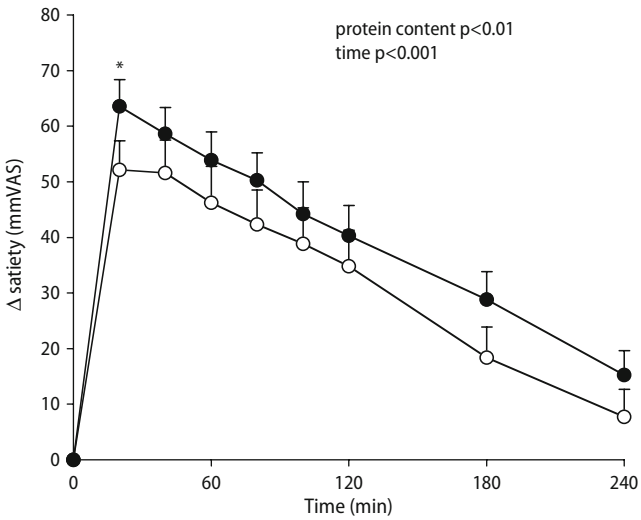

Fig. 1 Changes in satiety (mmVAS) after a soy breakfast given as a custard with either 10 En% or 25 En% from protein expressed as delta compared to baseline in 25 subjects (men and women). Values are mean values + SEM. *Open circle* 10% of energy from soyprotein, *filled circle* 25% of energy from soyprotein. ANOVA repeated measures showed an effect of protein content ($P < 0.01$) and time ($P < 0.001$) on satiety ratings; analysis per time point showed a difference in satiety at 20 min after breakfast (*$P < 0.05$)

Analysis per time point revealed that after a breakfast with 25% of energy from soyprotein satiety ratings were more increased than after a breakfast with 10% of energy from soyprotein at 20 min (64 ± 5 vs. 52 ± 5 mmVAS, $P < 0.05$, Fig. 1).

Taste perception

Pleasantness of taste scores were 53 ± 5 and 54 ± 4 mmVAS for the breakfast with 10 and 25% of energy from protein, respectively (ns).

Glucose

Baseline plasma glucose concentrations were not different between treatments. There was a protein content × time interaction effect on glucose concentrations ($P < 0.05$), peak values were higher after a breakfast with 10% of energy from soyprotein whereas glucose concentrations stayed more increased at 120 and 180 min after a breakfast with 25% of energy from soyprotein (Fig. 2). Glucose concentrations were different over time ($P < 0.001$, Fig. 2).

Analysis per time point revealed that glucose concentration was more increased after a breakfast with 25% of energy from soy than after a breakfast with 10% of energy from soy at 180 min ($P < 0.05$, Fig. 2).

Insulin

Baseline plasma insulin concentrations were not different between treatments. The insulin response expressed as AUC was more increased after a breakfast with 25% of energy from soyprotein than after a breakfast with 10% of energy from soyprotein (7,520 ± 929 vs. 4,936 ± 468 mU/l h, $P < 0.01$).

There was no protein content × time interaction effect (ns), whereas protein content ($P < 0.001$) and time ($P < 0.001$) both had an effect on insulin concentrations (Fig. 3). Insulin concentrations were more increased after a breakfast with 25% of energy from protein than after a breakfast with 10% of energy from protein ($P < 0.001$) and there were differences over time ($P < 0.001$, Fig. 3).

Analysis per time point revealed that insulin concentrations were more increased after a breakfast with 25% of energy from soy than after a breakfast with 10% of energy from soy at 60, 120, and 180 min ($P < 0.01$, $P < 0.001$ and $P < 0.01$ respectively, Fig. 3).

Ghrelin and GLP-1

Baseline plasma ghrelin and GLP-1 concentrations were not different between treatments. There was no protein content × time interaction effect or effect of protein content on ghrelin and GLP-1 concentrations (ns), only time had an effect on ghrelin ($P < 0.001$) or

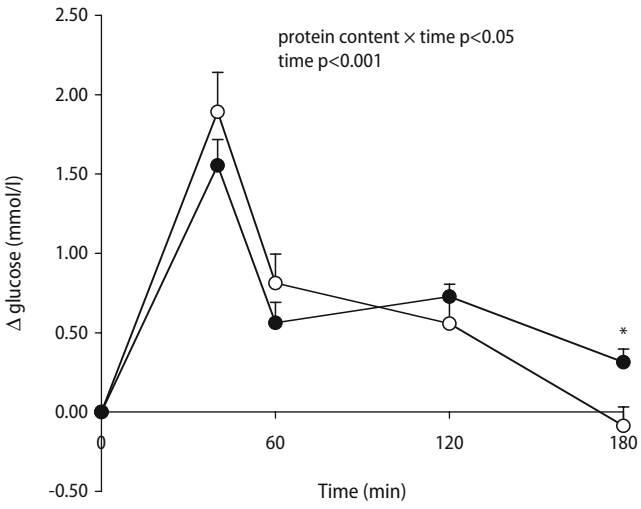

Fig. 2 Changes in glucose concentrations (mmol/l) after a soy breakfast given as a custard with either 10 En% or 25 En% from protein expressed as delta compared to baseline in 25 subjects (men and women). Values are mean values + SEM. *Open circle* 10% of energy from soyprotein, *filled circle* 25% of energy from soyprotein. ANOVA repeated measures showed a protein content × time interaction effect ($P < 0.05$) and an effect of time ($P < 0.001$) on glucose concentrations; analysis per time point showed a difference in glucose concentrations at 180 min (*$P < 0.05$)

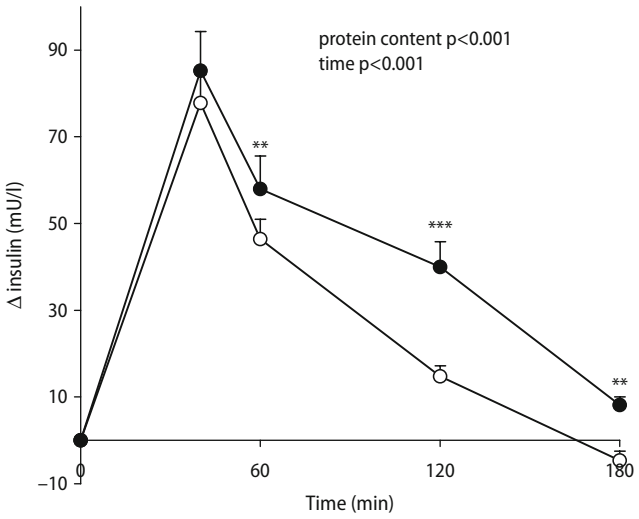

Fig. 3 Changes in insulin concentrations (mU/l) after a soy breakfast given as a custard with either 10 En% or 25 En% from protein expressed as delta compared to baseline in 25 subjects (men and women). Values are mean values + SEM. *Open circle* 10% of energy from soyprotein, *filled circle* 25% of energy from soyprotein. ANOVA repeated measures showed an effect of protein content ($P < 0.001$) and time ($P < 0.001$) on insulin concentrations; analysis per time point showed a difference in insulin concentrations at 60 (**$P < 0.01$) 120 (***$P < 0.001$) and 180 min (**$P < 0.01$)

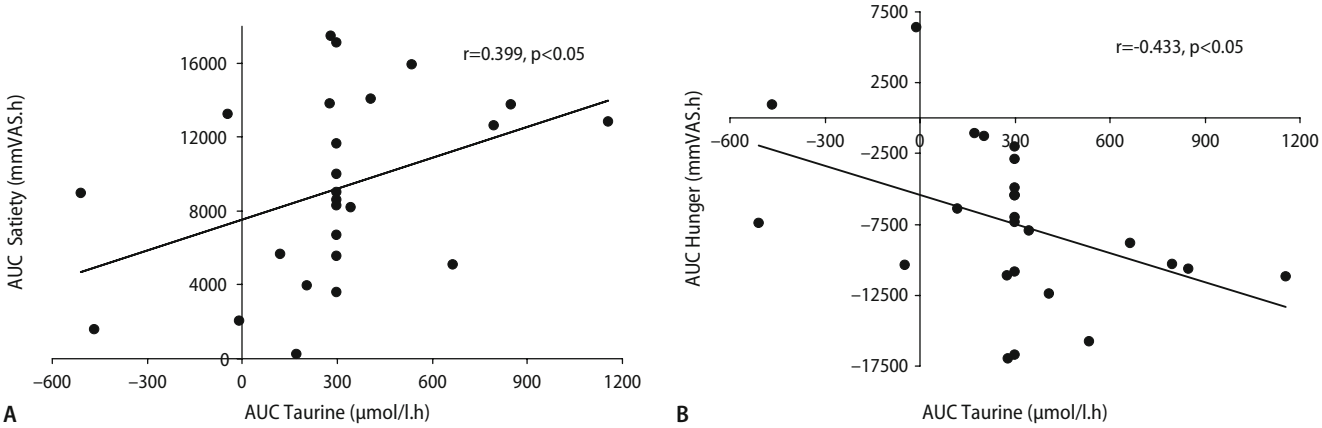

Fig. 4 Relation between satiety responses (mmVAS/h) and taurine responses (μmol/l h, **a**) and hunger responses (mmVAS/h) and taurine responses (μmol/l h, **b**) after a breakfast with 25% of energy from soyprotein in 25 subjects (men and women). The AUC of satiety was a function of the AUC of taurine ($r = 0.399$, $P < 0.05$) and the AUC of hunger was also a function of the AUC of taurine ($r = -0.433$, $P < 0.05$)

GLP-1 concentration ($P < 0.001$). Analysis per time point revealed that there were no differences in ghrelin or GLP-1 concentrations between a breakfast with 25% of energy from soyprotein and a breakfast with 10% of energy from soyprotein (data not shown).

Correlations

The AUC of satiety and hunger scores after the breakfast with 25% of energy from soy were a function of the AUC of the amino acid taurine (satiety: $r = 0.399$, $P < 0.05$; hunger: $r = -0.433$, $P < 0.05$, Fig. 4).

Amino acids and urea

Baseline plasma amino acid and urea concentrations were not different between treatments. The AUC of the response of glutamic acid, asparagine, serine, glutamine, histidine, glycine, threonine, citrulline, arginine, alanine, taurine, alpha-aminobutyric acid, tyrosine, valine, methionine, isoleucine, phenylalanine, tryptophan, leucine, ornithine, lysine, branched-chain amino acids (BCAA), sum amino acids (sum AA), and urea are presented in Table 2; significant differences between treatments are indicated. The AUC of nearly all amino acids was more increased after the breakfast with 25% of energy from protein than after the breakfast with 10% of energy from ($P < 0.05$, Table 2).

The changes in taurine concentrations over time are shown in Fig. 5. There was a protein content × time interaction effect on taurine concentrations ($P < 0.001$) and an effect of time on taurine concentrations ($P < 0.001$, Fig. 5). Analysis per time point revealed that taurine concentrations were more increased at 40, 60, and 80 min after a breakfast with 25% of energy from soyprotein than after a breakfast with 10% of energy from soyprotein ($P < 0.001$, $P < 0.001$ and $P < 0.01$ respectively, Fig. 5).

The AUC of the urea response was more increased after a breakfast with 25% of energy from protein

Table 2 AUC of amino acid (μmol/l·h) and urea (mmol/l·h) responses after a soyprotein breakfast given as a custard with either 10 En% or 25 En% from protein in 25 subjects (men and women)

	Soy	
	10%	25%
Glutamate	209 ± 534	3,264 ± 643***
Asparagine	5,684 ± 238	13,958 ± 278***
Serine	3,669 ± 327	10,277 ± 416***
Glutamine	1,296 ± 2881	7,818 ± 943*
Histidine	2,054 ± 495	4,314 ± 241**
Glycine	2,160 ± 610	6,760 ± 675***
Threonine	3,975 ± 553	11,500 ± 544***
Citrulline	−894 ± 152	−273 ± 136**
Arginine	6,248 ± 517	17,924 ± 669***
Alanine	32,396 ± 2,585	41,833 ± 2,408**
Taurine	307 ± 120	297 ± 72
Alpha-aminobutyric acid	122 ± 78	443 ± 100*
Tyrosine	2,439 ± 322	11,091 ± 509***
Valine	5,696 ± 786	22,855 ± 870***
Methionine	−785 ± 367	954 ± 233**
Isoleucine	5,143 ± 326	18,154 ± 450***
Phenylalanine	2,984 ± 236	8,098 ± 285***
Tryptophan	253 ± 254	2,571 ± 197***
Leucine	4,948 ± 477	21,071 ± 1,393***
Ornithine	2,978 ± 196	7,918 ± 411***
Lysine	8,812 ± 1,068	22,530 ± 922***
Branched-chain amino acids	1,5787 ± 1,492	62,081 ± 2,476***
Sum amino acids	89,695 ± 10,998	233,355 ± 8,463***
Urea	−30 ± 15	118 ± 15***

Values are mean values ± SEM, ANOVA repeated measures
* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

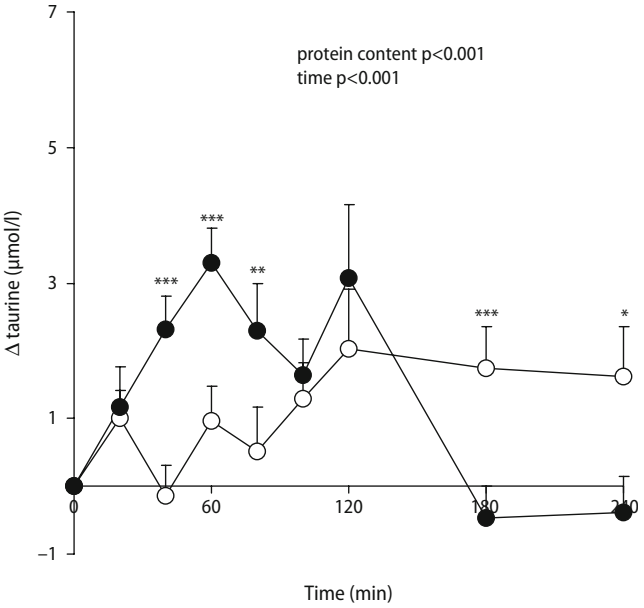

Fig. 5 Changes in taurine concentrations (µmol/l) after a soy breakfast given as a custard with either 10 En% or 25 En% from protein expressed as delta compared to baseline in 25 subjects (men and women). Values are mean values + SEM. *Open circle* 10% of energy from soyprotein, *filled circle* 25% of energy from soyprotein. ANOVA repeated measures showed a protein content × time interaction effect ($P < 0.001$) and an effect of time ($P < 0.001$) on taurine concentrations; analysis per time point showed a difference in taurine concentrations at 40 (*** $P < 0.001$), 60 (*** $P < 0.001$), 100 (** $P < 0.01$), 180 (*** $P < 0.001$) and 240 min (* $P < 0.05$)

than after a breakfast with 10% of energy from protein ($P < 0.001$, Table 2).

Energy intake

The sensitive moment in time to determine EI in the second set of experiments was based upon the differences in glucose and insulin responses, still being present at 180 min after breakfast, therefore this moment was chosen to offer lunch.

Energy intake at lunch was 3,098 ± 286 and 3,212 ± 280 kJ after the breakfast with 10 and 25% of energy from protein, respectively (ns).

Discussion

Satiety ratings were higher after a breakfast with 25% of energy from soyprotein compared with a breakfast with 10% of energy from soyprotein. The iso-energetic breakfasts contained 20% of the individual's total daily energy requirements and were of the same color, viscosity, and did not differ significantly in taste.

There may be two different reasons for the observed difference in satiety. The increased satiety after the breakfast with 25% of energy from soyprotein coincided with an increased insulin response. Insulin is a metabolic satiety signal [26, 32] and may explain the increased perceived satiety.

The satiating properties of soyprotein also showed to be dependent on specific amino acid responses. A positive relationship was observed between satiety or hunger suppression and the concentration of the amino acid taurine. Due to the different pattern of taurine concentrations over time, the AUC of the taurine response was not significantly different between the two breakfasts. After a breakfast with 25% of energy from soyprotein, taurine concentrations increased more than after a breakfast with 10% of energy from soyprotein. However, after 120 min taurine concentrations decreased to levels below baseline after a breakfast with 25% of energy from soyprotein whereas taurine concentrations remained slightly elevated after a breakfast with 10% of energy from soyprotein. Therefore, there was no difference in taurine response expressed as AUC over 4 h compared with the breakfast with 10% of energy from soyprotein. Nevertheless, in those subjects with an increased AUC of taurine an increased satiety and an increased hunger suppression was observed.

Plant proteins do not contain taurine [11], however, it can be synthesized from cysteine in the liver [20]. Since soyprotein is rich in cysteine, this may have been the source of the elevated taurine concentrations [9]. The liver readily synthesizes taurine when cysteine supply is adequate. It is formed via sequential actions of cysteine dioxygenase (CDO) which gives rise to cysteinesulfinate and cysteinesulfinate decarboxylase (CSD). Cysteinesulfinate is then decarboxylated by CSD to hypotaurine which is further oxidized to taurine [19]. Healthy obese subjects were found to have lower taurine concentrations compared with non-obese age- and sex-matched healthy control subjects [10]. Moreover, taurine ingestion has been shown to decrease body weight in hyperglycemic obese mice after a 5% taurine diet for 10–14 weeks [6]. Furthermore, intake of 3 g taurine per day for 7 weeks reduced body weight significantly compared with placebo in a group of overweight and obese human subjects [34]. In addition, taurine has also been shown to depress food intake in mice [23]. The present study for the first time showed a direct relation between satiety and/or hunger suppression and taurine concentrations in humans. Sea foods are rich in taurine [11], the satiating effects of fish observed by Uhe et al [24] may be explained by the increased taurine concentrations. Thus, in addition to the literature the present study shows that an increased taurine concentration leads to increased feelings of satiety and suppressed hunger. To summarize, the increased satiety observed after the breakfast with 25% of energy from soyprotein may be caused by both

increased insulin and taurine concentrations that were associated with satiety.

Despite the increased satiety after the breakfast with 25% of energy from soyprotein and the assessment of the sensitive moment in time, we observed no difference in ad lib EI at lunch between a breakfast with 25% of energy from soyprotein versus a breakfast with 10% of energy from soyprotein. Also no differences were present between a breakfast with 25 or 10% of energy from soyprotein with respect to the orexigenic and anorexigenic hormones ghrelin and GLP-1. Soyprotein thus does not contain the specific amino acids that trigger the secretion of these orexigenic and anorexigenic hormones considerably.

To summarize, a breakfast with 25% of energy from soyprotein was more satiating than a breakfast with 10% of energy from soyprotein, related to taurine concentrations. Insulin response after the breakfast with 25% of energy from soy was increased, whereas there were no differences in GLP-1 or ghrelin responses. In conclusion, a high soyprotein breakfast was more satiating than a normal soyprotein breakfast related to elevated taurine and insulin concentrations.

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Conflict of interest None of the authors had a personal or financial conflict of interest.

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