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High-oleic peanuts increase diet-induced thermogenesis in overweight and obese men

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Abstract

Background: **Evidences suggest that nuts consumption can improve energy metabolism.**

Purpose: **This study aimed to compare the effects of acute ingestion of high-oleic and conventional peanuts on appetite, food intake, and energy metabolism in overweight and obese men.**

Methods: **Seventy one subjects (29.8 ± 2.4 kg/m²) were assigned to the groups: control (CT, n = 24); conventional peanuts (CVP, n = 23); high-oleic peanuts (HOP, n = 24). Subjects consumed 56 g of peanuts (CVP and HOP) or control biscuits (CT) after overnight fasting. Thereafter, energy metabolism was evaluated over 200 minutes, during which diet-induced thermogenesis (DIT) and substrate oxidation were analyzed. Appetite sensation was recorded for 3 hours. Statistical analyses were performed using the SAS software considering 5% as the significance level.**

Results: **Postprandial energy expenditure and DIT were significantly higher in HOP than in CVP. Substrate oxidation did not differ between groups. Only HOP presented score below 100 indicating incomplete compensation. CT and CVP showed a complete caloric compensation (scores > 100). Regarding appetite sensation, CVP group felt less "full" than HOP and CT. After 3 hours, satiety score of CVP returned to baseline, whereas HOP and CT remained significantly higher. Hunger scores returned to baseline in CVP and CT and they were maintained significantly lowered in HOP.**

Conclusion: **High-oleic peanuts contributed to higher DIT, higher sensation of fullness and incomplete compensation for energy intake compared to conventional peanuts and may be useful to dietary intervention to reduce body weight.**

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Key words: *Obesity. Energy metabolism. Substrate oxidation. Appetite. Oleic fatty acid.*

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CACAHUETE ALTO-OLEICO AUMENTA LA TERMOGÉNESIS INDUCIDA POR LA DIETA EN HOMBRES CON SOBREPESO Y OBESIDAD

Resumen

Antecedentes: **Las pruebas sugieren que el consumo de frutos secos puede mejorar el metabolismo energético.**

Propósito: **Este estudio tenía por finalidad comparar los efectos de la ingesta aguda de cacahuetes con alto contenido en oleico y cacahuetes convencionales sobre el apetito, el consumo de alimentos y el metabolismo energético in hombres con sobrepeso y obesos.**

Métodos: **Se distribuyó a 71 individuos (29,8 ± 2,4 kg/m²) a los grupos: control (CT, n = 24); cacahuetes convencionales (CVP, n = 23); cacahuetes con alto contenido en oleico (HOP, n = 24). Los individuos consumieron 56 g de cacahuetes (CVP y HOP) o control (CT) tras un ayuno nocturno. Posteriormente, se evaluó el metabolismo energético a lo largo de 200 minutes, durante los cuales se analizaron la termogénesis inducida por la dieta (TID) y la oxidación de sustratos. La sensación de apetito se registró durante 3 horas. Se realizaron los análisis estadísticos con el programa SAS considerando un nivel de significación del 5%.**

Resultados: **El consumo de energía posprandial y la TID fueron significativamente superiores en el HOP que el CVP. La oxidación de sustratos no difirió entre los grupos. Sólo el HOP presentó una puntuación por debajo de 100, lo que indicaba una compensación incompleta. El CT y el CVP mostraron una compensación calórica completa (puntuaciones > 100). Con respecto a la sensación de apetito, el grupo CVP se mostró menos "lleno" que los grupos HOP y CT. A las 3 horas, la puntuación de saciedad del CVP volvió a la situación basal, mientras que en los grupos HOP y CT permanecía significativamente superior. Las puntuaciones de hambre volvieron a la situación basal in los grupos CVP y CT y se mantuvieron significativamente por debajo a las del grupo HOP.**

Conclusión: **Los cacahuetes con alto contenido en oleico contribuyen a una mayor TID, mayor sensación de plenitud y una compensation incompleta del consumo de energía en comparación con los cacahuetes convencionales y pueden ser de ayuda como intervention dietética para disminuir el peso corporal.**

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Palabras clave: *Obesidad. Metabolismo energético. Oxidación de sustrato. Apetito. Ácido graso oleico.*

Abbreviations

ANOVA: Analyses of variance.
BMI: Body mass index.
CHO: Carbohydrate.
CT: Control group.
CVP: Conventional peanuts group.
DIT: Diet-induced thermogenesis.
HOP: High-oleic peanuts group.
MUFA: Monounsaturated fatty acids.
piAUC: Positive incremental area under the curve.
REE: Resting energy expenditure.
rm-ANOVA: Repeated measure analyses of variance.
SEM: Standard error of the means.
SFA: Saturated fatty acids.

Introduction

Obesity represents one of the major risk factors for the development of other metabolic disease. Its appropriate treatment is essential for the maintenance of good health status[1,2]. Therefore, many studies have been conducting to verify the metabolic effects of seed on overweight individuals[3-11].

Evidences suggest that peanuts ingestion may favor body weight control by reducing food intake and by modulating energy metabolism and substrate oxidation[5,6]. Nuts satiating and thermogenic proprieties can be attributed to their high contents of dietary fiber, protein, and unsaturated fatty acids[7,12].

There is general agreement that protein has greater effect on diet-induced thermogenesis (DIT) than carbohydrate and fat[1,13-17]. Besides, dietary fiber improves satiety and reduces hunger sensation[15,18-21]. Since peanuts is one of the highest protein contents nuts (≈24%), and it also has ≈8% of dietary fiber, its consumption may contribute to appetite control and to increase DIT[3,5].

Energy metabolism improvement of overweigh individuals after peanuts oil ingestion has been reported[6]. The authors attributed the results to the peanuts fatty acids profile. It is known that monounsaturated fatty acids (MUFA) increase body fat oxidation while saturated fatty acids (SFA) contribute for lower DIT and are prone to be stored in adipose tissue[6,22-26]. Despite its high energy density (≈6 kcal/g) and high-fat content (≈50%), peanuts is an excellent source of MUFA[3,5].

Oleic acid is the major MUFA of peanuts. There is a great interest in producing high-oleic peanuts since this fatty acid preserves the sensory and antioxidant proprieties by decreasing lipid peroxidation during storage[27-30]. However, there is a lack of knowledge about the effects of high-oleic peanuts in human metabolism[11]. Thus, this trial aimed at comparing the effects of acute intake of high-oleic and conventional peanuts on appetite, food intake, and energy metabolism in overweight and obese men.

Subjects and methods

Subjects

One hundred fifty potential men were recruited by public advertisements and posted flyers. Subjects underwent a brief nutritional screening, which included measurement of body weight and height, and filling out a questionnaire about medical, sports, and nutritional history. They were required to be aged between 18 and 50 years, with body mass index (BMI) ranging from 26 to 35 kg/m^2 and stable weight (± 3 kg) during the previous 3 months. Subjects presenting any chronic/acute diseases were not included. Other exclusion criteria were the use of any medication that might affect the results of the study, and/or be under weight-loss diets over 3-months prior to the study; drinking more than 168 g of alcohol/week. The study was approved by the ethical committee in human research of the Federal University of Viçosa, MG, Brazil (protocol: 185/2011). The study procedures were conducted in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. All participants signed a written informed consent and received no financial compensation or gifts for their cooperation.

Study Design

This was a one-day intervention randomized trial. After successfully completing the screening, seventy one subjects were randomly assigned to the experimental groups: Control (CT; n = 24); Conventional peanuts (CVP; n = 23); High-oleic peanuts (HOP; n = 24). They were explained about the protocol (fig. 1). Subjects received a standard dinner to be consumed the night prior to the assessments (see *Test meal* section). After an overnight fasting, subjects consumed the test meal, which included 56 g of conventional or high-oleic peanuts (CVP and HOP) or control biscuits. The analysis included measurements of anthropometry, body composition, appetite subjective sensation, food intake, resting energy expenditure (REE), DIT, and substrate oxidation.

Test meal

The night prior to the assessments, subjects were required to eat a standard dinner which consisted of 109 g of a instant plain noodles (Nissin®) with 5 g of parmesan cheese, and 200 mL of grape juice (731 kcal; 65.1% from carbohydrate, 7.6% from protein, and 28.3% from fat). This meal was intended to reduce DIT and substrate oxidation during fasting conditions since the thermic effect of protein may remain longer than 7 hours[1].

On the test day, subject consumed within 15 minutes one of the three test meals according to the experimen-

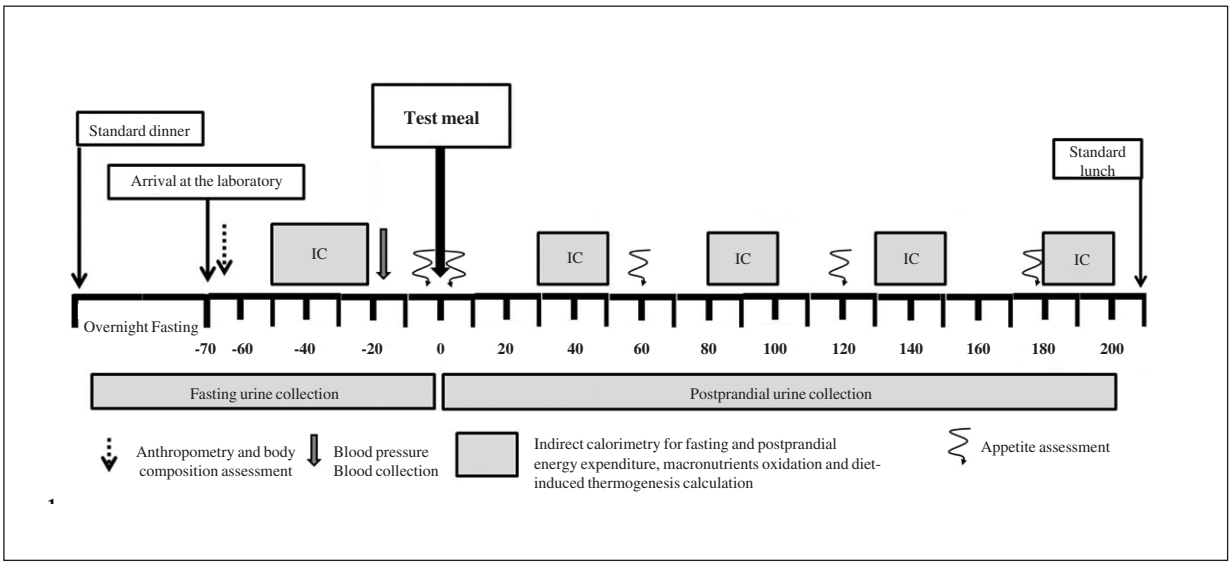

Fig. 1.—Experimental protocol.

tal group. Each test meal was calculated to provide 25% of each subject's daily energy requirement (706 ± 73 kcal). They had the same energy density and provided 35% of the calories from carbohydrate, 16% from protein, and 49% from fat. They consisted of a strawberry flavored milk shake and 56 g of unpeeled roasted peanuts (conventional or high-oleic) or control biscuits.

Conventional (IAC-886) and high-oleic (IAC-505) peanuts were prepared in dry heat for 25 minutes at 180 ºC being revolved every 5 minutes. After cooling, 56 g of peanuts were packed in vacuum and stored at -20°C for further use. Samples were analyzed for macronutrients and dietary fiber contents according to validated methods[31,32]. This portion of conventional and high-oleic peanuts contains, respectively, 13.6 and 12.8 g of carbohydrates, 16.8 and 16.3 g of proteins, 24.0 and 24.7 g of fat, and 5.0 and 5.5 g of dietary fiber (0.2 and 0.7g of soluble; 4.8 and 4.8 g of insoluble). Oleic fatty acid represents 51.0% of total fat in conventional peanuts and 81.5% in high-oleic peanuts.

Control biscuits were developed in the laboratory to offer similar amount of macronutrients and fiber, and energy density of the mean composition of both peanuts types. Its ingredients, in each portion, consisted of egg (30 g), whey protein supplement (13.8 g), whole wheat flour (11.6 g), margarine (9.6), hydrogenated vegetable shortening (8.6 g), soybean oil (7.2 g), dietary fiber supplement (1.6 g), sesame seed (1.5 g), wheat bran (1.2 g), salt (0.7 g), and powder yeast (0.3 g). It was prepared 1-2 days before each test day. The centesimal composition of control biscuits were also analyzed[31,32]. One portion of 56g contains 12.2 g of carbohydrates, 16.4 g of proteins, 24.6 g of fat, and 4.7 g of dietary fiber (0.4 g of soluble; 4.3 g of insoluble). Oleic fatty acid represents 35.2% of total fat.

The milk shake was prepared right before its consumption and consisted of whole milk powder, whey protein supplement, Nesquik® strawberry powder, soybean oil, water, and ice. The proportion of ingredients varied since it was prepared to complete the calories and macronutrients content respecting the macronutrient proportion previously described in this section. Besides, in order to control the volume of 500 mL/meal, additional water was given to subjects.

After completing all the study protocol, a 750 kcal meal was offered. It consisted of a sandwich, fruit juice (250 mL), and apple (130 g).

Dietary intake assessment

Subjects provided 3-days food records (two non-consecutive week days and one weekend day) filled out the week before the assessments. On test-day, subjects were also required to fill out a food record until bed time. A dietitian reviewed the food records with the subjects to check for errors or omissions. All the food records were analyzed by the same dietitian using a specific computer software system (Dietpro 5.2i, 2007. Agromídia Software Sistemas-Universidade Federal de Viçosa) based on Brazilian food composition tables[33,34].

Dietary compensation for the test meal calories consumed was calculated as described by Kirkmeyer and Mattes[35] using the equation: (energy intake from the self-selected diet + energy from the test meals) minus (actual energy intake from the self-selected diet + energy from test meals) divided by the energy value of the test meals. Results were expressed as percentage. A value of 100 represents an adjustment of free-feeding intake that exactly offsets the energy contributed by the peanuts. Values below 100 indicate incomplete compensation.

Appetite assessment

One hundred millimeter visual analog scales were used for appetite assessment. These scales include words anchored at each end, expressing the most positive and negative rating, to assess hunger, satiety, fullness, and prospective food consumption[36]. Subjects were carefully trained to use the questionnaire prior the test. The questionnaires were made as small booklets showing one question at a time. Subjects were instructed to rate the appetite dimensions by marking the scale at the point that was most appropriate to their feeling at that time and they could not refer to their previous ratings when marking the questionnaire. Appetite ratings were recorded immediately before and after the test meal consumption, and hourly for three hours (fig. 1). The results were expressed as the positive incremental area under the curve ($_{pi}$AUC) of the scores.

Measurements and calculations

Subjects were instructed not to consume caffeine and alcohol, to refrain from heavy physical activity and to maintain a regular sleep-wake schedule (8 hours/night) during 72-hours before test day. They were also instructed to fast overnight prior to the assessments and to minimize activity in the morning of the measurements. Body weight, height, and waist and hip circumferences were taken with subjects standing straight, barefoot and wearing only light shorts. Body weight and composition were assessed by a bioelectrical impedance analysis device (Tanita, model TBF-300, Tanita Corporation) in full compliance with the manufacturer guidelines. After at least 10 minutes of resting, blood pressure was measured with the use of a sphygmomanometer by trained specialists.

Respiratory gas exchange was measured by indirect calorimetry using a ventilated respiratory canopy (Deltatrac II, MBM-200; Datex Instrumentarium Corporation) in full compliance with the manufacturer guidelines. The volume of oxygen consumption and carbon dioxide production were measured over 30 minutes under fasting conditions. Then, the REE was obtained from the device. To evaluate DIT and substrate oxidation, the gas exchange was measured four times over 200 minutes after test meal ingestion during 20 minutes within 30 minutes intervals (fig 1). Subjects were asked to be awake and minimize motion during measurements. DIT was calculated as the incremental increase in energy expenditure above REE, expressed as percentage of the meal calories[13]. Cumulative energy expenditure (kcal x 200 minutes) was expressed as $_{pi}$AUC[13,37]. To calculate carbohydrate and fat oxidation, the urinary nitrogen was analyzed by Kjeldahl method in timed urine samples, which were collected during fasting period and over 200 minutes after meal consumption (fig 1). Fasting and postprandial substrate oxidation were calculated using the equations propose by Frayn[38] and expressed as mg/min and as its $_{pi}$AUC.

Subjects' daily energy requirements were calculated by multiplying the measured REE by a physical activity coefficient. This coefficient depended on the physical activity level of each subject, which was evaluated by using the *International Physical activity Questionnaire* and classified according to FAO/WHO/UNU (2001)[39-41].

In order to preserve subjects' health, peanut samples were analyzed for aflatoxin content. Briefly, immunoaffinity columns were used (Aflatest®, Vicam) for sample purification. The toxin was quantified by using a high-performance liquid chromatography with fluorescence detection. The post-column derivatization was done using a Kobra cell® electrochemical cell.

Statistical analysis

The $_{pi}$AUCs were calculated using GraphPad Prism (Version 5; GraphPad software Inc) using the trapezoidal method. The statistical analyses were performed using the SAS statistical package (Version 9.2; SAS Institute Inc). Normality and homogeneity of variance were evaluated by Shapiro-Wilk and Levene tests, respectively. Accordingly, parametric or nonparametric tests were performed.

Variables were compared between groups using One-way analyses of variance (ANOVA) followed by Tukey's test or using the Kruskal-Wallis test followed by Dunn's test, as appropriate. Two-way repeated-measures ANOVA were applied to test the differences between groups throughout the test day for energy metabolism variables and appetite sensation with treatment and time as repeated factors. Paired t-tests or Wilcoxon test were performed to compare habitual dietary intake with the test day intake. Power analysis was calculated using the analyst procedures of the SAS software. It indicated that a sample of 23 per group would permit detection of a treatment effects with more than 99% of power. The rejection level of significance used was 5%. Results are presented as mean ± SEM.

Results

Seventy one subjects were randomized to the trial. Subjects' characteristics at baseline (fasting condition), including anthropometry, body composition, blood pressure, and energy metabolism variables did not differ between groups (table I). Physical activity level (1.57 ± 0.01) was not significantly different between groups nor did the habitual food intake (*data not shown*).

Fasting resting metabolic rates were not different between groups (0.95 ± 0.02 kcal/min; p = 0.7621) and increased after the consumption of all test meals (p <

Table I
Subjects characteristics at baseline (fasting conditions)

	Overall (n = 71)	*CT (n = 24)*	*CVP (n = 23)*	*HOP (n = 24)*
Age (years)	27.1 ± 0.9	26.3 ± 1.6	27.6 ± 1.5	27.4 ± 1.7
Body weight (kg)	94.1 ± 1.3	94.2 ± 2.5	93.1 ± 2.0	94.9 ± 2.1
BMI (kg/m^2)	29.8 ± 0.3	29.8 ± 0.6	29.5 ± 0.4	30.1 ± 0.5
Waist (cm)	101.5 ± 0.9	101.9 ± 1.8	100.7 ± 1.2	101.8 ±1.6
Hip (cm)	108.7 ± 0.6	109.2 ± 1.1	108.1 ± 1.2	108.9 ± 1.1
Fat mass (kg)	25.3 ± 0.7	25.6 ± 1.5	24.2 ± 1.1	26.1 ± 1.2
Body fat percentage (%)	26.7 ± 0.5	26.8 ± 0.9	25.8 ± 0.8	27.3 ± 0.8
Fat free mass (kg)	68.8 ± 0.8	68.7 ± 1.4	68.9 ± 1.3	68.8 ± 1.3
Total body water (kg)	50.4 ± 0.6	50.3 ± 1.0	50.4 ± 1.0	50.4 ± 1.0
Systolic BP (mmHg)	119.0 ± 1.6	121.0 ± 4.0	118.0 ± 1.7	118.0 ± 2.2
Diastolic BP (mmHg)	69.0 ± 1.5	73.0 ± 2.8	67.0 ± 2.0	70.0 ± 2.6
REE(kcal/day)	1954 ± 22.3	1930 ± 41.2	1964 ± 43.9	1968 ± 31.3
CHO oxidation (mg/min)	173.2 ± 6.8	178.7 ± 14.3	173.8 ± 11.5	167.2 ± 9.5
Fat oxidation (mg/min)	49.2 ±2.5	47.8 ± 4.7	50.1 ± 3.6	49.7 ± 4.7

Values are mean ± SEM. There was no difference between groups (ANOVA; $p > 0.05$). *CT*: control group. *CVP:* conventional peanut group. *HOP:* high-oleic peanut group. *BMI:* body mass index. *REE*: resting energy expenditure. *CHO*: carbohydrate.

0.001). Energy expenditure increased significantly after the consumption of test meals (fig. 2). It is remarkable that at 200 minutes, the HOP postprandial energy expenditure was 9.25% higher than the resting energy expenditure in fasting state, which was similar to the value found for CT (9.04%), and both values were significantly higher than CVP value (6.46%). There was no group-time interaction in rm-ANOVA ($p > 0.05$). Energy expenditure expressed as $_{pi}$AUC was significantly higher in HOP (636.6 ± 43.7) than in CVP (492.9 ± 35.1), yet, peanuts meals did not differ significantly from CT meal (582.7 ± 37.7) (fig. 2A).

DIT after each meal ingestion is illustrated in figure 2B. Since test meals were isocaloric, the thermic effect reflected the $_{pi}$AUC of energy expenditure for each meal. The DIT of high-oleic peanut (3.43 ± 0.24%) was significantly higher than the DIT of conventional peanut (2.63 ± 0.17%) but did not differ significantly from the control meal (3.19 ± 0.23%). The DIT from CT was similar to the CVP ($p > 0.05$).

Carbohydrate and fat oxidation in fasting resting state did not differ between groups (table I). Figure 2C-D illustrates the changes in substrate oxidation after test meal intake. Overall, carbohydrate oxidation increased but returned close to baseline values after 200 minutes (172.4 ± 9.8 mg/min). Conversely, fat oxidation increased significantly in all groups at 200 minutes compared to fasting state (66.7 ± 3.7 mg/min). The $_{pi}$AUC for carbohydrate (179.9 ± 12.7; overall) and fat oxidation (47.3 ± 5.0; overall) did not differ between groups ($p > 0.05$).

The food record filled out at the assessments day showed that dietary intake did not differ between groups neither from habitual dietary intake ($p > 0.05$). Besides, the difference between dietary intake at the assessment day and habitual diet (Delta-Δ) was not significantly difference between groups (*data not shown*).

There was no significant difference between groups for energy compensation score. However, an important clinical result of this study must be highlighted. Only HOP showed a mean score below 100 (84.0 ± 23.2), which indicates incomplete compensation for caloric intake. CT (102.3 ± 19.9) and CVP (134.2 ± 22.7) meals contributed to a complete compensation for meal test calories.

Concerning the $_{pi}$AUC of fullness sensation score (fig. 3), the subjects felt significantly less "full" after the CVP meal (105.1 ± 15.8) than did those from HOP (158.6 ± 15.5) and CT (155.8 ± 15.52) ($p = 0.0384$). Satiety did not differ significantly between groups after test meal intake (CT: 143.6 ± 16.9; CVP: 126.8 ± 15.1; HOP: 136.8 ± 16.7). Regarding prospective food consumption and hunger sensation, it must be noticed that their analyses represents the opposite of the preceding questions. Therefore, the higher $_{pi}$AUC is the lower the subjective sensation is. The CT subjects were significantly less prone to eat something else (54.8 ± 9.9) than did subjects from CVP (33.9 ± 16.5) and HOP (31.2 ± 10.3). For hunger sensation no significant difference between groups was verified after test meal ingestion (CT: 99.5 ± 15.7; CVP: 93.9 ± 13.9; HOP: 113.4 ± 16.8).

There were no group-time interaction in rm-ANOVA for appetite scores ($p > 0.05$). Interestingly, all groups increased the "fullness" sensation ($p < 0.001$), yet, while CT and HOP maintained their scores significantly higher during the 3 hours ($p < 0.001$), at the third hour the "fullness" score of CVP was similar to baseline ($p = 0.9925$). All of the meals increased significantly the subjects' satiety ($p < 0.001$) and its score remain higher for all groups until the second hour after meal intake ($p < 0.01$). However, at the third hour the

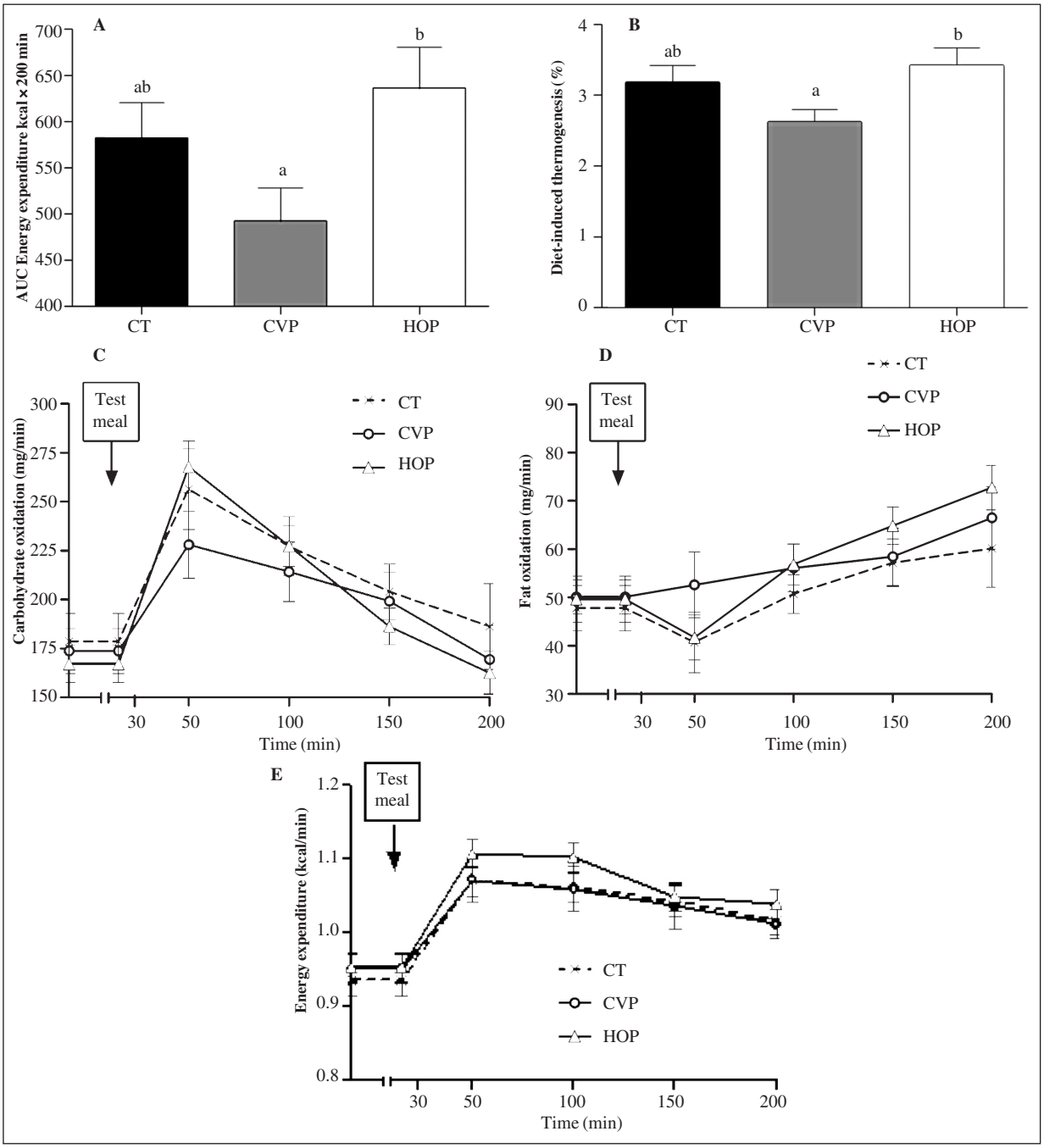

Fig. 2.—Mean (± SEM) changes in cumulative energy expenditure (A), diet-induced thermogenesis expressed as the percentage of each meal calories (B), carbohydrate oxidation (C), fat oxidation (D) and resting energy expenditure (E) during 200 min after test meal intake. Bars with different letters are significantly different (ANOVA; $p < 0.05$). A mixed model with "meal" as a fixed effect and "subject" as a random effect was used to estimate each meal effect on cumulative substrate oxidation. There was no group-time interaction for substrate oxidation (rm-ANOVA/ $p > 0.05$). CT, control group; CVP, conventional peanut group; HOP, high-oleic peanut group; piAUC, positive incremental area under the curve.

satiety score in CVP did not differ from baseline ($p = 0.0857$), while the HOP ($p = 0.0243$) and CT ($p = 0.0037$) did. For hunger sensation score, all groups showed significant reduction after meal intake, but after 2 hours CVP and CT scores returned to baseline values ($p = 0.2009$; $p = 0.1683$, respectively), while HOP maintained it lower than at baseline ($p = 0.0177$).

Discussion

DIT and fat oxidation are important key elements on energy balance regulation, thus, a decrease in these elements could result in body fat accumulation[42,43]. On the other hand, an increase in DIT and fat oxidation may lead to body fat reduction. This trial showed that

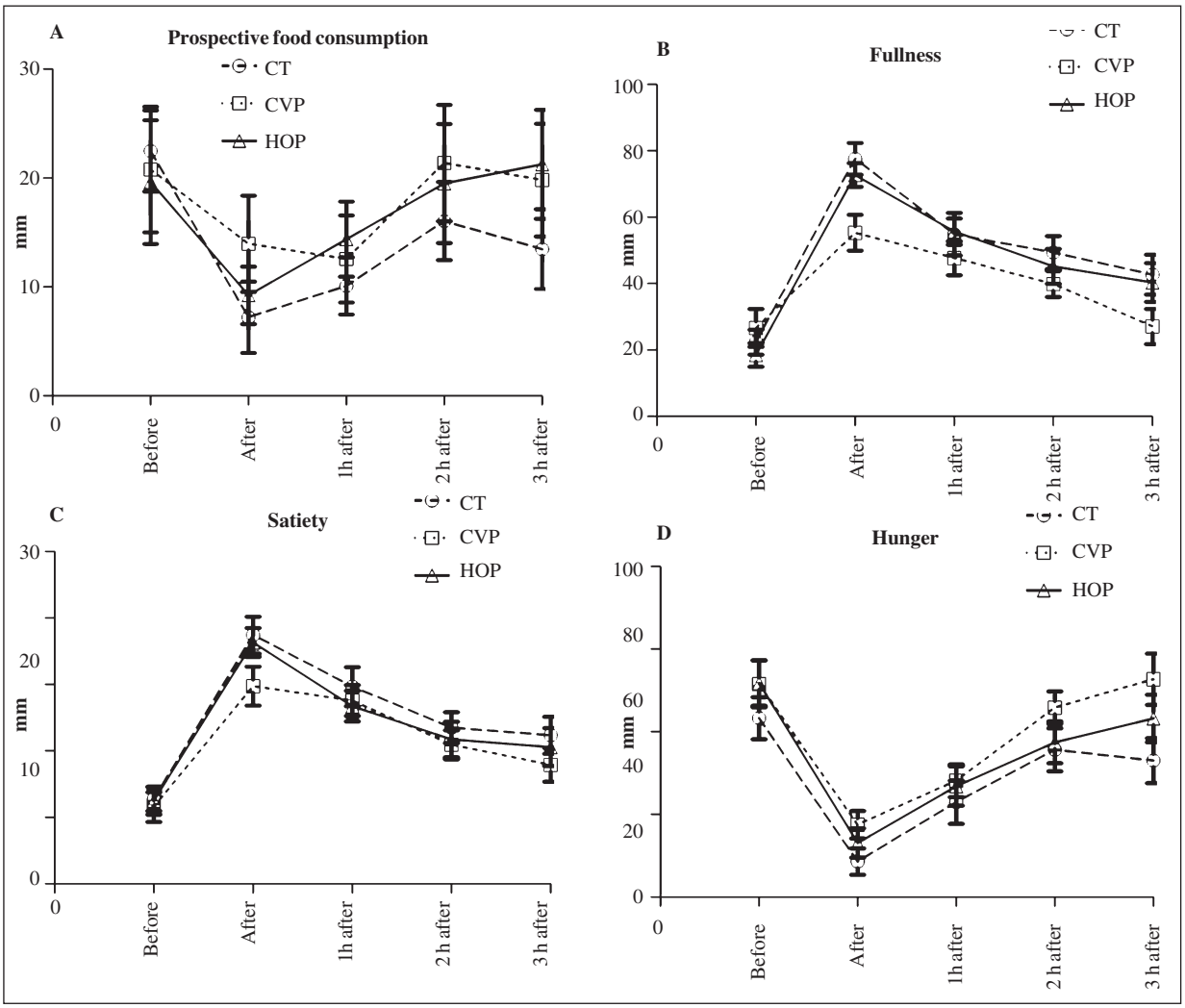

Fig. 3.—Mean (± SEM) changes in scores for prospective food consumption (A), fullness (B), satiety (C) and Hunger (D) after test meals intake. A mixed model with "meal" as a fixed effect and "subject" as a random effect was used to estimate each meal effect on scores over the time. Adjustments on p values were done by using Tukey-Kramer's multiple group comparison procedures. CT, control group; CVP, conventional peanut group; HOP, high-oleic peanut group.

high-oleic peanuts contribute for greater increment on DIT (%) and on cumulative energy expenditure ($_{pi}$AUC) compared to conventional peanuts. It is well documented that carbohydrate and fat lead to lower DIT than do protein since high-protein food/meal induces body protein synthesis and also increases the cost of deamination and convertion to glucose[13,17]. However, in our study the difference in DIT can not be attributed to peanuts' protein contents since both have similar amount of protein (30.0 and 29.1%, respectively).

The fatty acids structure including number, position, and configuration of double bonds influences metabolic rate [5,23]. Therefore, it can be inferred that the difference in DIT, as well as in $_{pi}$AUC of energy expenditure reported in this trial may be due to the fatty acid profile of the tested peanuts. Oleic acid represents the major fatty acid of high-oleic type (81.5%), which means 59.8% more oleic acid than the conventional type.

It is well known that unsaturated fatty acids contribute for higher DIT and fat oxidation compared to SFA[24,26,42]. Besides, SFA have higher propensity to be stored in adipose tissue than unsaturated fatty acids, which are preferable oxidized and stimulates body fat oxidation[6,22-24,26]. The authors of studies in which MUFA intake increased DIT and fat oxidation, suggested that this occurs due to a higher stimulation of the sympathetic nervous system by the MUFA than by other fatty acids[23,44].

Few studies have evaluated the effects of peanuts on energy metabolism. Moreover, we did not find studies in which the effects of high-oleic peanuts in energy metabolism were tested. Alper and Mattes[5] designed a crossover trial with 15 lean subjects that consumed conventional peanuts (≈ 505 kcal/day). In their study it was verified an increment of 11% ($p < 0.01$) in REE without changing the DIT ($p > 0.05$) after 19-weeks[5]. However, in an 8-week intervention clinical trial, con-

ventional peanuts oil intake promoted a significant increment (5%) in REE in overweight subjects (n = 24)[6]. In that study, overweight subjects (n = 24) the consumption of the peanut oil contributed for an increment of 5% in REE ($p < 0.01$), while an increment of 11% ($p < 0.01$) was verified when only men were included in analysis (n = 12).

Although, there were no significant differences between groups for dietary data after the assessments, including in dietary compensation score, an incomplete compensation for caloric intake was verifyed only in HOP. If the findings of this acute trial, persists for chronic consumption of high-oleic peanuts, it could be inferred that this type of peanuts do not pose a risk for weight gain. Besides, as described by Kirkmeyer and Mattes, there are great evidences that nuts consumers are not heavier than subjects those who do not eat nuts frequently[35].

According to Acheson et al, foods that contribute to higher DIT, also increase satiety[13]. The results for DIT showed that HOP had higher DIT than CVP ($p < 0.05$), which is consistent with the incomplete compensation for caloric intake found in HOP group. The composition of the test peanuts may have influenced the appetite, which contributed for this clinical difference found for caloric intake compensation. However, the difference in fatty acids profile of test food, including conventional peanut, may not be the only factor for this compensation since, according to Kirkmeyer and Mattes,the degree of fatty acid saturation is not an important factor for appetite sensation[35].

There is general agreement that food rich in protein and dieatry fiber are more satiating[13,19]. The foods tested in this trial had similar amount of protein, as described before. The total dietary fiber contents of test foods were also similar since the high-oleic peanuts have 9.8% of dietary fiber while the conventional peanuts have 8.9% and the control biscuits have 8.3%. However, high-oleic peanuts have more soluble fiber (1.17%) than conventional peanuts (0.32%) and control biscuits (0.62%). Thus, soluble fiber contents may partially explain the results described below for appetite subjective sensation.

The type of protein used to prepare the control biscuits may be one limitation of the present study since it may have influenced the subjective appetite sensation and the DIT results in the CT group. There are evidences that different protein sources can modulate the energy metabolism and appetite[13,17]. The main protein source of the control biscuits was whey protein, while main one used on HOP and CVP meals came from the peanuts. According to Acheson at al., animal protein rather than vegetable protein improve protein turnover and favor protein synthesis, which contributes to increase DIT, indirectly influencing appetite[13]. Yet, how different protein source influences satiety is less clear.

To our knowledge, this is the first study that evaluates the effects of high-oleic peanuts on energy metabolism and appetite. A study conducted by O'Byrne et al evaluated the long-term effect of a low-fat diet containing high-oleic peanuts on serum lipoprotein profiles[11]. They found that high-oleic peanuts improved serum lipid profile[11]. Thus, high-oleic peanuts seem to have other beneficial metabolic effects also. Yet, further investigations are necessary to evaluate the effects of a chronic intake of high-oleic peanut on metabolism, including the variables of the present study, as well as other variables such as body weight and composition, and biochemical parameters. Regular consumption of high-oleic peanut probably will increase DIT, which in turns would increase total energy expenditure contributing to negative energy balance, since peanuts may also lead to lower caloric intake by reducing hunger and caloric compensation, and increasing satiety.

Conclusion

The results of the present study showed that high-oleic peanuts increased DIT compared to conventional peanuts in overweight and obese men. Furthermore, high-oleic peanuts contributed to interesting effects on appetite sensation. The fatty acids profile of the high-oleic peanuts seem to be the main factor responsible for these effects. A long-term clinical trial is necessary to elucidate the potential of high-oleic peanuts within a dietary intervention in modulating appetite and energy metabolism and as an outcome in controling obesity.

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Conflict of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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