Effect of Peanut Oil Consumption on Energy Balance

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ABSTRACT

Objective: To determine the effects of peanut, olive, and safflower oil consumption on appetite, dietary compensation and body weight.

Methods: One hundred and twenty-nine (63 male, 66 female) adults (25.05 ± 5.58 years) with a mean body mass index (BMI) of 22.09 ± 2.58 were recruited from three countries: Brazil, Ghana and the United States. Participants were randomized into a control group and 3 intervention groups; peanut oil, olive oil, and safflower oil. Those in the intervention groups consumed daily milkshakes containing the group's assigned oil for 8 weeks along with their normal diet. No dietary advice was provided. Resting metabolic rate (resting energy expenditure [REE]) and the thermogenic effect of feeding (TEF) were measured by indirect calorimetry. During weeks 0, 4, and 8 body weight, body composition, and appetite were measured, activity logs were kept, and blood samples were collected.

Results: The total energy intake of participants in the active treatment groups increased significantly during the intervention weeks compared with baseline. The percentage of energy derived from fat also increased significantly, while that from carbohydrate decreased. No significant changes were observed in REE, TEF, or activity over the intervention. Body weight increased significantly by week 8 in all 3 intervention groups.

Conclusion: The inclusion of oils rich in poly- or monounsaturated fatty acids in the diet did not elicit precise macronutrient or energy compensation.

INTRODUCTION

Foods with high satiety value should help to curb unpleasant hunger sensations and aid compliance with weight-management regimens. Foods with high energy density are often regarded as problematic for energy balance because their weak satiation value may result in passive overconsumption.[1] However, it is not clear that energy density is a reliable

Table 1. Participant characteristics (n=129)

	Country			
	Brazil (n=32)	**Ghana (n=64)**	**USA (n=33)**	**Total**
Height (m)	1.70 ± 0.02 *	1.65 ± 0.02†	1.71 ± 0.02*	1.68 ± 0.09
Weight (kg)	64.65 ± 1.56*	59.56 ± 1.11†	66.79 ± 2.49*	62.67 ± 0.96
BMI (kg/m^2)	22.16 ± 0.25	21.75 ± 0.33	22.72 ± 0.54	22.09 ± 0.23
Waist-to-hip ratio	0.78 ± 0.01	0.79 ± 0.01	0.81 ± 0.01	0.79 ± 0.01
REE (kcal)	1587.23 ± 42.72*	1490.59 ± 17.92†	1635.70 ± 50.02*	1551.40 ± 19.44

REE=resting energy expenditure
Values are mean ± SEM
*†Statistically significant difference in height, weight, and REE between countries (P<0.05).

predictor of appetitive or dietary responses to an item. High-energy, dense foods with other attributes that promote a level of satiety commensurate with the food's energy content would not be expected to pose a threat to energy balance. Peanuts have a high energy density (about 5.9 kcal/g) yet epidemiological reports indicate there is an inverse association between frequency of nut consumption (where peanuts are the primary contributor) and body mass index (BMI).[2-4] Intervention trials reveal consumption of large quantities of peanuts has little effect on body weight.[5,6] Similar observations have been made with almonds[7] and pecans.[8] The limited impact of nut consumption on body weight is due, in part, to the strong dietary compensation they elicit. That is, there is a spontaneous reduction of energy intake at other times of the day that offsets a large proportion (typically 55%-75%) of the energy contributed by the nuts.[6,9-14] One constituent of peanuts and some tree nuts that is hypothesized to contribute to their strong satiation effect is their high content of unsaturated fatty acids. Animal studies show unsaturated fatty acids are a potent appetite suppressor,[15,16] although the human literature is less consistent.[17-19] Further clarification of this mechanism was one objective of this study.

The efficiency of monounsaturated fatty acid (MUFA) and polyunsaturated fatty acid (PUFA) oxidation also reduces the likelihood that they will be stored, which would limit their influence on body weight.[20] Indeed, a recent study with obese males revealed isocaloric substitution of a diet high in MUFA resulted in weight loss compared with a diet rich in saturated fatty acids.[21] In other work, weight gain was noted during carbohydrate supplementation, whereas no change was observed during isocaloric MUFA supplementation (P.L, unpublished data, 2003). In community-dwelling adults, the provision of peanuts results in a diet composition enriched in MUFA.[22] A second aim of this project was to quantify the effects on energy balance and body weight of oils that vary in composition of fatty acids. Comparisons were made between peanut and olive oil to determine whether there were differences in response to two oils high in MUFA, as well as safflower oil, to contrast the effects of MUFA-rich versus PUFA-rich oils.

METHODS

Subjects

One hundred and twenty nine adults, aged 18–50 years were recruited through advertisements in three countries:

Table 2. Macronutrient composition of study milkshakes per serving

Composition	Peanut Oil Milkshake	Olive Oil Milkshake	Milkshake Safflower Oil
Energy (kcal)	557.09	557.09	557.09
Protein (g)	7.38	7.38	7.38
Carbohydrate (g)	17.75	17.75	17.75
Total fat (g)	50.73	50.73	50.73
PUFA (g)	17.86	7.14	39.29
MUFA (g)	25	35.71	7.14
SFA (g)	7.14	7.14	3.57

PUFA=polyunsaturated fatty acids; MUFA=monounsaturated fatty acids; SFA=saturated fatty acids.

Ghana (N = 64), Brazil (N = 32), and the United States (N = 33). There were 66 nonpregnant, nonlactating females and 63 males. To be eligible for the study, participants had to be nonsmokers, unrestrained eaters (score <14 on the Three Factor Eating Questionnaire),[23] have a BMI of 18-25 kg/m^2, have no acute or chronic diseases, and not be taking medication. Participants had stable body weight (± 3 kg within the prior 3 months) and control over the purchase and preparation of at least 50% of the foods they consumed. Participant characteristics are presented in Table 1. The Ghanaian participants had lower height and weight than the other groups, but comparable BMI. They also had a lower resting energy expenditure (REE).

Experimental Design

The study was a single-blind, randomized, 8-week intervention with four parallel arms. There was a 1-week baseline period preceding the intervention. The intervention entailed provision of peanut oil (N=32), olive oil (N=32), safflower oil (N=33), or no oil (N=2) daily for 8 weeks. Participants received no dietary guidance.

General Protocol

Anthropometric and energy expenditure measurements, as well as dietary assessments, were made during the baseline week and at weeks 4 and 8 of the intervention (except energy expenditure, which was not measured at week 4). Activity logs were also completed at weeks 2 and 6. Participants were randomly assigned to 1 of the 4 experimental groups after the baseline period. They reported to the test center every day for 8 weeks and if they were in an intervention group, they consumed a milkshake containing a particular type of oil. Participants were allowed to take the shakes (frozen) with them in plastic cups over the weekend. To minimize potential social desirability effects that could bias dietary reports, participants were told that the purpose of the study was to assess the effects of diet on lipid levels.

Intervention Loads

The oils used were as follows: peanut oil (Hollywood Enriched Gold Peanut Oil, The Hain Celestial Group Inc, Melville, NY), olive oil (Filipo Berio Extra Light Tasting Olive Oil, Salov North America Corp, Hackensack, NJ), and safflower oil (Hollywood Enriched Expeller Pressed Safflower Oil, The Hain Celestial Group Inc, Uniondale, NY). The provided test foods were as follows: Even skimmed milk (France), Milo (Nestle, Accra, Ghana), Vanilla Essence (Arôme,

Table 3. Nutrient intakes (inclusive of intervention oil) estimated from the 3-day dietary records across treatment groups (mean ± SEM)

	Diet Groups			
	Peanut Oil	**Olive Oil**	**Safflower Oil**	**Control**
Energy (kcal/d)				
Baseline	2056.54 ± 111.75 *	2192.82 ± 106.21 *	1892.47 ± 104.54 *	1845.23 ± 109.81
Week 4	2320.52 ± 121.13 †	2379.74 ± 115.12 †	2046.99 ± 113.30 †	2109.88 ± 119.81
Week 8	2287.77 ± 129.16 †	2528.11 ± 122.75 †	2299.96 ± 120.82 †	1931.46 ± 126.91
Fat (% energy)				
Baseline	31.28 ± 1.42 *	32.14 ± 1.35 *	33.14 ± 1.32 *	30.95 ± 1.39
Week 4	43.62 ± 1.73 †	44.75 ± 1.64 †	45.45 ± 1.61 †	31.99 ± 1.70
Week 8	43.14 ± 1.49 †	45.66 ± 1.42 †	44.38 ± 1.40 †	34.02 ± 1.47
SFA (g)				
Baseline	20.95 ± 1.85	23.21 ± 1.85	21.72 ± 1.79	19.69 ± 1.92
Week 4	27.62 ± 2.16	25.99 ± 2.16	24.20 ± 2.09	24.69 ± 2.24
Week 8	27.73 ± 2.35	28.93 ± 2.35	25.37 ± 2.28	22.59 ± 2.44
MUFA (g)				
Baseline	20.84 ± 2.08 *	23.29 ± 1.98 *	22.13 ± 1.95 *	19.99 ± 2.04
Week 4	46.12 ± 2.84 †	54.26 ± 2.69 †	29.12 ± 2.66 †	24.78 ± 2.79
Week 8	44.40 ± 2.73 †	58.75 ± 2.59 †	37.24 ± 2.55 †	21.81 ± 2.68
PUFA (g)				
Baseline	11.19± 1.31 *	12.79 ± 1.24 *	11.38± 1.22 *	10.43± 1.28
Week 4	28.17 ± 2.31 †	21.26 ± 2.19 †	42.27 ± 2.16 †	14.35 ± 2.27
Week 8	27.83 ± 3.09 †	23.94 ± 2.94 †	44.06 ± 2.07 †	13.12 ± 3.03
Protein (% energy)				
Baseline	14.12 ± 0.54	14.12 ± 0.51	13.92 ± 0.49	13.54 ± 0.53
Week 4	13.91 ± 2.31	10.96 ± 2.19	17.02 ± 2.12	14.38 ± 2.26
Week 8	13.32 ± 1.15	12.69 ± 1.09	13.91 ± 1.06	15.42 ± 1.13
Carbohydrate (% energy)				
Baseline	55.24 ± 1.82 *	53.82 ± 1.73 *	54.37 ± 1.68 *	56.25 ± 1.79
Week 4	47.76 ± 3.60 †	45.85 ± 3.31 †	45.85 ± 3.31 †	55.39 ± 3.54
Week 8	48.67 ± 1.99 †	43.26 ± 1.23 †	43.26 ± 1.83 †	57.39 ± 1.96
Weight of food (g)				
Baseline	1598.78 ± 144.97	1851.44 ± 140.21	1537.36 ± 138.00	1522.36 ± 144.97
Week 4	1500.60 ± 139.47	1651.51 ± 134.89	1509.43 ± 132.77	1627.16 ± 139.47
Week 8	1568.46 ± 143.65	1591.61 ± 138.94	1603.92 ± 136.75	1487.53 ± 143.65

PUFA=polyunsaturated fatty acids; MUFA=monounsaturated fatty acids; SFA=saturated fatty acids.
*†Statistically significant differences in energy/micronutrient intake within a treatment group between baseline and week 4 and baseline and week 8.

Bordeaux, France), Nescafe (Nestle, Cote d'Ivoire), Canderel (NUTRASWEET, Merisant, UK). A mixture of flour, skim milk, and sweetener called farinha lactea was blended in the shakes to mask the flavor of the oils. Farinha lactea was developed by Universidade Federal de Viscosa, Viscosa, Brazil, and consists of 4 tbs flour, 1tbs powdered skimmed milk, 1tbs sugar, and 1 tsp

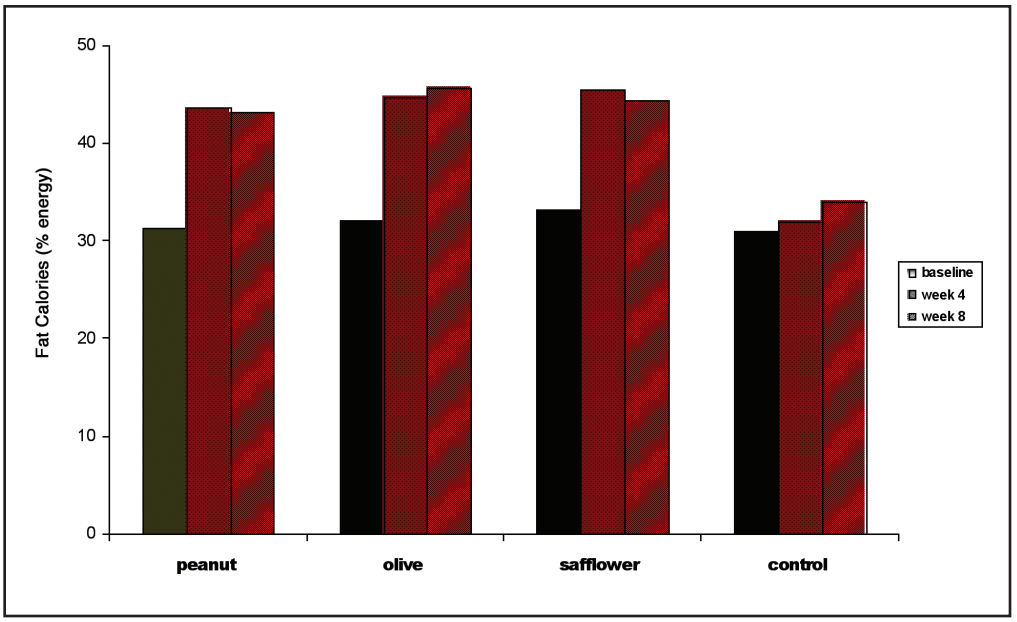

Figure 1. Fat intake as a percentage of the total daily energy intakes of participants consuming peanut oil, olive oil, and safflower oil for 8 weeks.

water. It is prepared by sprinkling water on the flour while stirring continuously over medium heat for 20-30 minutes and mixing in the sugar and milk after cooling. All ingredients were blended for 3 minutes and served chilled. The nutrient composition of the shakes is presented in Table 2. The shakes provided 30% of each individual's estimated REE.

Anthropometric and Body Composition Measurements

Anthropometric measurements were taken at weeks 0, 4, and 8. Body height was measured at baseline in the standing position. Body weight was measured in a fasting state with participants in street clothes or paper gowns. Bioelectrical impedance was used to measure body composition (Tanita Body fat Analyser TBF-105 from Tanita Corporation, Arlington, Illinois). Waist and hip circumference were measured with a non-stretch tape.

Dietary Assessments

Dietary intake was assessed through diet records filled out by participants at baseline and weeks 4 and 8 of the intervention. Records were kept on 3 days (2 weekdays and 1 weekend day). Participants were trained to estimate portion sizes. Food composition tables appropriate for each population were used to analyze diet records to ensure the most accurate assessment of intake possible given the varying food supplies in each country. All data were coded by a single individual in each country.

Energy Expenditure Assessment

Energy expenditure was measured at baseline and during week 8 of the intervention. Both REE and the thermogenic effect of food (TEF) were measured by indirect calorimetry using a metabolic cart and a ventilated respiratory canopy (VMax 29, SensorMedics Corporation, Yorba Linda, CA). Analyzers were calibrated with room air and standard calibration gas mixtures (4% CO_2, 24% O_2, 72% N_2 and 0% CO_2, 26% O_2, 74% N_2, respectively). Energy expenditure was calculated based on the Weir equation

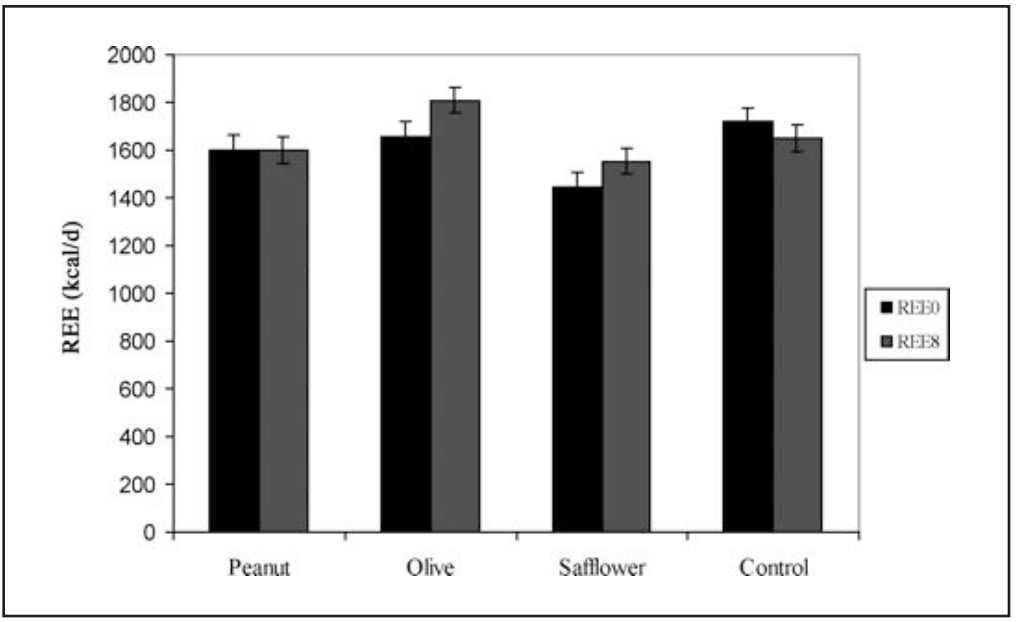

Figure 2. Mean (SE) resting energy expenditure pre and post-intervention (ie, consumption of 300 kcal of peanut, olive, or safflower oil daily for 8 weeks).
REE=resting energy expenditure.

(RMR kcal/day = $3.94(VO_2)$ + $1.106(V_{CO2})$ X 1.44).[24] Participants were asked to refrain from strenuous activity, alcohol, and caffeine for 24 hours prior to testing. They reported to the laboratory in the morning after a 12-hour fast and rested for at least 10-30 minutes. REE measurements were performed in the supine position for 30 minutes. Readings for the last 20 minutes were averaged and served as the participant's estimated REE. Participants then consumed the type of shake they were provided daily. TEF was measured at 15-minute intervals for the next 5 hours. Participants were required to stay awake and refrain from bodily movements during the measurements. Participants were allowed to watch television during the measurement to help them stay awake. Participants in the "no oil" group were given shakes containing peanut oil during the measurement of TEF.

Activity Logs
Two 24-hour activity logs were completed on 2 of the days diet was recorded at weeks 0, 4, and 8. Additional activity logs were completed on weeks 2 and 6. The type and duration of all activities were recorded throughout the day. The logs were analyzed using NutriQuest software from WCB-McGraw Hill (Version 1.0, Oak Leaf Enterprises, Solution Design Inc, Phoenix, AZ).

Statistical Analysis
Statistical analyses were performed with the SPSS software package, version 10.0 (SPSS Inc. Chicago, IL). Treatment effects were tested by repeated measures analysis of variance (ANOVA). The criterion for statistical significance was $P<0.05$, two-tailed.

RESULTS

Food Intake
Mean daily nutrient consumption values are shown in Table 3 for the peanut oil, olive oil, safflower oil, and no-oil groups, respectively. Macronutrient intakes were comparable between the groups at base-

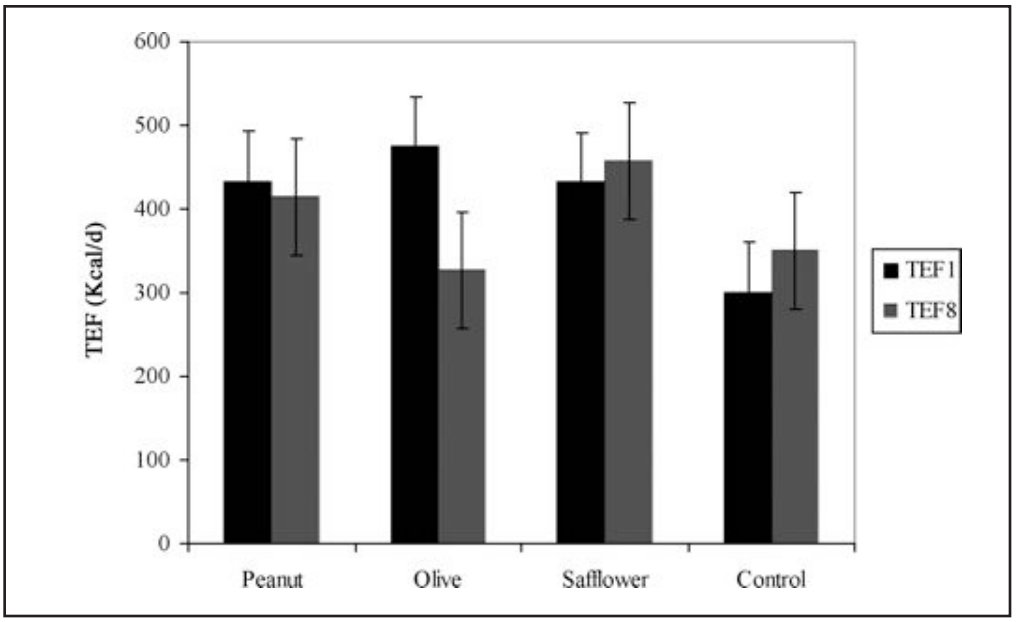

Figure 3. Mean (SE) thermogenic effect of feeding pre- and post-intervention (ie, consumption of 300 kcal of peanut, olive, or safflower oil daily for 8 weeks).
TEF = thermogenic effect of feeding.

line. However, the average energy intake increased with the addition of the oil loads in the 3 active intervention groups. Thus, energy intakes during weeks 4 and 8 of intervention were significantly higher than energy intake at baseline ($P<0.001$). No difference in energy intake was observed in the no-oil group over time.

The percentage of energy obtained from fat also increased significantly ($P<0.001$) at weeks 4 and 8 within the intervention groups (Figure 1). Saturated fatty acids (SFA), MUFA, and PUFA intakes increased significantly, with the SFA intake increasing significantly in the control group as well ($P<0.01$). The percentage of energy derived from carbohydrate was significantly lower at weeks 4 and 8 relative to baseline for all intervention groups, except the no-oil group. The SFA intake in the United States was significantly higher than in Brazil ($P=0.023$) or Ghana ($P=0.006$), participants in Ghana had the lowest SFA intake. PUFA intake was also significantly lower in Ghana than intake levels in both the United States and Brazil ($P<0.03$).

Energy Expenditure

REE-No significant differences in REE were observed within or between the groups during the intervention, except that the olive oil group had a higher value at week 8 compared with the safflower oil group (Figure 2). There were no significant differences between countries.

TEF-The thermic effect of feeding (TEF) for the various oils did not differ over time in any treatment group (Figure 3). No group differences were observed at baseline or week 8. The TEF in the Brazilians was significantly higher than in the Americans ($P<0.01$).

Activity-Compared to baseline, there was a small, but statistically significant, increase in self-reported physical activity during week 2 of the intervention

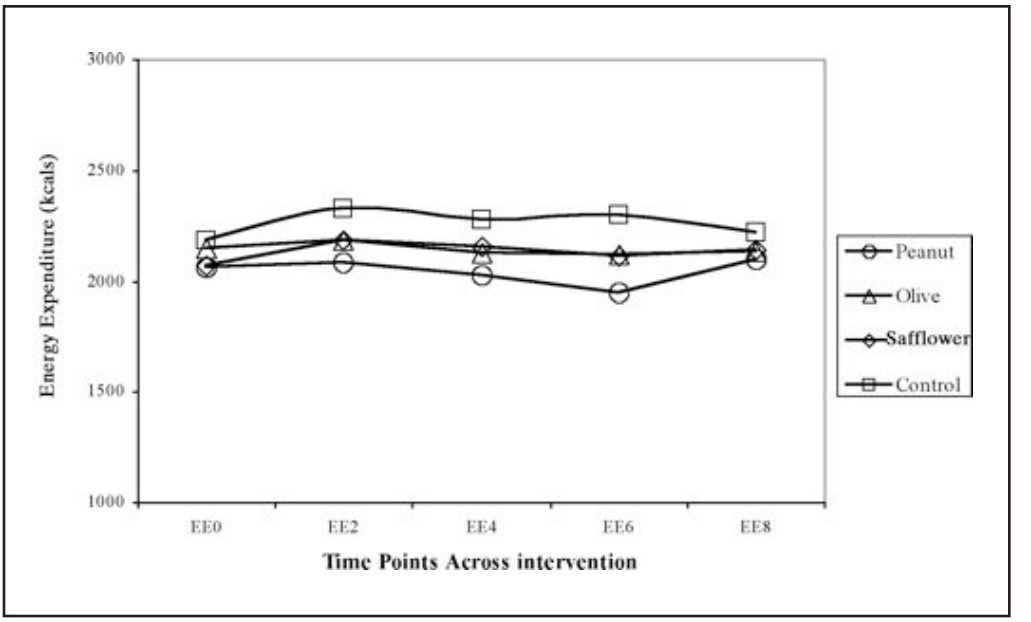

Figure 4. Estimated energy expenditure across time between treatment groups.

(P<0.005), but no other comparison with baseline was statistically significant (Figure 4). Participants in the control group reported significantly higher activity levels than those in the peanut oil intervention (P<0.02). There were no significant differences within the treatment groups. US participants reported significantly higher activity levels compared with Ghanaians (P<0.01).

Body Weight

The mean body weight values are shown in Table 4. Body weight increased significantly at week 4 in the olive oil group (P<0.02), but not in the peanut or safflower oil groups. However, at week 8, there was a significant increase in weight relative to baseline in all 3 oil intervention groups (P<0.05), but not among controls. Generally, Ghanaians had a significantly lower body weight than participants in Brazil and the United States (P<0.02).

DISCUSSION

Peanuts are nutrient dense, but they are also energy dense. Thus, recommendations to increase their consumption raise concern about their potential contribution to positive energy balance and weight gain at a time when overweight/obesity is prevalent and increasing worldwide. Earlier reports suggested that despite their high energy content, consumption was not associated with weight gain.[3,4] Mechanistic hypotheses have included a high satiety value and oxidation rate of the MUFA contained in peanuts. Satiety is partly a function of prior experience with a food and fatty acid oxidation is modified by diet composition, an attribute with cultural determinants. Thus, there are environmental and physiological factors that could account for responses to peanut consumption. One way to explore or isolate these factors is to compare populations with varying cuisines. The countries represented in this study differ markedly in peanut use: whole peanuts and peanut soups and sauces are widely consumed in Ghana; whole nuts are the principle form of intake in Brazil; and whole nuts and butter are the popular routes of ingestion in the United States. This study

Table 4. Body weight across the different treatment groups

Treatment Group	Week 1	Week 4	Week 8
Peanut	62.43 ± 1.99 *	62.67± 1.94 *	63.10± 1.9 †
Olive	63.64 ± 2.05 *	64.17 ±1.99 †	64.59± 2.03 †
Safflower	63.05 ± 1.95 *	63.39± 1.90 *	63.69± 1.93 †
Control	66.30 ± 2.01	66.17±1.96	66.07± 1.99

*†Statistically significant differences in body weight within a treatment group between baseline and week 4 (olive oil only) or baseline and week 8

contrasted the effects of peanut oil, olive oil (another rich source of MUFA), and safflower oil (high in PUFA) consumption on energy balance in the 3 countries. The study samples in each country included educated, urban-dwelling, healthy, young adults. The lack of substantive differences across these cultures is consistent with a more biological basis for the study findings.

A small, but statistically significant increase of body weight occurred in all treatment groups. No change occurred in the controls. However, the treatment-related increase was significantly lower than the theoretically predicted weight gain. Observed weight gain, specifically in the peanut oil treatment, was 0.7 kg compared with a possible predicted weight gain of 3.4 kg if no dietary compensation occurred. Expected weight gain was calculated assuming that a mean energy surplus of 500 kcal/day leads to weight of gain of 0.064 kg/day. Comparable changes of body weight were observed with the olive and safflower oils. This suggests the mechanism does not involve a unique property of peanut oil.

In prior work, the incorporation of whole peanuts to the habitual diet of healthy adults for 8 weeks resulted in a 1 kg increase in body weight.[6] This was lower than the expected weight gain of 3.6 kg. Part of the proposed explanation is that whole peanuts are not completely digested and the poor bioaccessibility of nut lipid results in increased fecal loss.[26,27] Levine and Silvis, reported a 4.5% increase of fecal fat content when subjects were fed with peanut oil as 95% of energy.[25] Although not as great a loss as noted with whole nuts (17.8%), it could contribute to the lower-than-expected weight gain. Furthermore, efficiency of MUFA and PUFA oxidation[20] reduces the likelihood that they will be stored, which would limit their influence on body weight. Isocaloric substitution of a diet high in MUFA for one richer in SFA in obese males has been associated with weight loss.[21]

The mean energy intake increased 12% in the peanut and olive oil groups and 15% in the safflower oil group during the intervention. No significant change was recorded in the no-oil group. The mean energy intakes were comparable between countries. These increases were observed because the oils failed to elicit complete compensation for the energy they provided. A full-fat diet combined with unrestrained eating leads to increased energy intake.[27] In contrast, restrained eating behavior with a full-fat diet prevented an increase in energy intake and body weight. The present study included only unrestrained eaters and corroborated the earlier findings.

Strong dietary compensation has been proposed to contribute to the limited impact of peanut consumption on body weight. Prior work with peanuts reveals that over two-thirds of the energy

they contribute is offset by spontaneous dietary adjustments at other times of the day.[6,28] Though this has been attributed to the high fiber, protein and hardness of whole nuts, their fatty acid composition is also a potential contributor.

The REE of participants was measured before and after the dietary intervention. No significant differences were observed within or between the treatment groups. An earlier study also noted no differences in REE over this time frame, with consumption of 500 kcal/day of whole peanuts (P.L., unpublished data, 2003). Alper and Mattes observed an 11% increase after 19 weeks of ingestion.[6] Whether a longer intervention with the peanut oil would have revealed a shift is not clear, but there was no trend in this direction. The differences between this and the other work may be attributable to other components present in the whole nuts such as their protein or fiber content. No statistically significant change of TEF was observed across treatments. This is consistent with earlier work with whole nuts.[6]

There is increasing evidence for an important role of physical activity in body weight management. Physical activity is negatively associated with skin fold thickness[29,30] and changes in physical activity are inversely associated with changes in body weight.[31] In this study, no significant increase in energy expenditure was noted in any treatment group over time. Moreover, the US sample reported higher energy expenditure than the Ghanaian sample, but the change of body weight was comparable in the 2 groups. Thus, increased physical activity was not the mechanism accounting for the observed lower-than-predicted weight gain in this trial.

Poor study compliance is not a factor in the lower-than-predicted weight gain. With few exceptions, the shakes were consumed in the laboratory under supervision.

CONCLUSIONS

In summary, there were no significant differences between the peanut oil, olive oil, and safflower oil treatment groups on the major outcomes of energy intake, energy expenditure, and body weight gain. The consumption of an additional 300 kcal as peanut, olive, or safflower oil, coupled with incomplete dietary compensation and no significant change in the components of energy expenditure (ie, REE, TEF, physical activity), led to a small, but significant increase in the body weight of participants within the 8-week intervention period. Given that the caloric load was larger than the recommended serving size of 1.5 oz/day and that peanut oil is more readily absorbed than the more commonly consumed whole peanuts, generalization of the results must be made cautiously. Taken together, the inverse association observed between peanut consumption and BMI is probably due to the combined properties of peanuts rather than the oil/MUFA content alone.

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