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ORIGINAL COMMUNICATION

The effect of grape-seed extract on 24 h energy intake in humans

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Objective: Since grape-seed extract has been shown to stimulate lipolysis *in vitro* and reduce food intake in rats, we assessed the efficacy of grape-seed extract with respect to energy intake (EI) and satiety.
Design: In a randomized, placebo-controlled, double-blind, cross-over study, 51 subjects (age 18–65 y, body mass index 22–30 kg/m^2) ate an *ad libitum* lunch and dinner twice in the University Restaurant for 3 days. Standard breakfasts and snacks were provided. Supplements were taken 30–60 min prior to each meal.
Results: In the total study population, no difference in 24 h EI was found between the grape-seed extract and placebo. However, in the subgroup of subjects (n=23) with an energy requirement $\geq$the median of 7.5 MJ/day, EI was reduced by 4% (ΔEI 352.1 kJ/24 h, P=0.05) after grape-seed extract compared to placebo treatment. Meanwhile, there were no significant differences in macronutrient composition, attitude towards eating, satiety, mood or tolerance.
Conclusions: Grape seed reduced 24 h EI, with on average 4% in subjects who had an energy requirement $\geq$7.5 MJ/day, without further effects on satiety, mood or tolerance. These findings suggest that grape seed could be effective in reducing 24 h EI in normal to overweight dietary unrestrained subjects, and could, therefore, play a significant role in body-weight management.
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Keywords: energy intake; grape seed; body-weight management

Introduction

Obesity increases the risk of multiple conditions, many of which are associated with a relatively high rate of morbidity and mortality, such as type II diabetes, hypertension and coronary heart disease (Burton & Foster, 1985; Pi-Sunyer *et al*, 1998). The risks associated with many of these comorbid conditions may be reduced with modest weight loss. Weight control methods often produce short-term success, but sustained weight maintenance is difficult to reach (Westerterp-Plantenga *et al*, 1998; Pasman *et al*, 1999). Moreover, the increasing prevalence of obesity (Kuczmarski *et al*, 1994) requires preventive treatments of obesity. Substances that reduce energy intake (EI) without a strong reduction in satiety may be useful. In this respect, we investigated the potential of grape-seed extract. With respect to the mechanism related to the possible effect of grape-seed extract, in animal models the polyphenols present in grape seed have shown to reduce food intake (Tebib *et al*, 1996; Wielinga *et al*, 2002) and to prevent weight gain (Tebib *et al*, 1996). *In vitro* experiments showed that these polyphenols stimulate lipolysis (Tebib *et al*, 1996; Ardevol *et al*, 2000), which is hypothesized to be particularly effective in overweight subjects who might show a reduced lipolysis (Fisher *et al*, 2002). Increased postprandial lipolysis may increase hepatic fat oxidation (Surina *et al*, 1993; Westerterp-Plantenga *et al*, 1999) and, thus, may affect satiety (Kamphuis *et al*, 2003; Langhans & Scharrer, 1987; McCarty & Scharrer, 1994; Scharrer, 1999). In this study, we assessed the efficacy of grape-seed extract with respect to EI and satiety, hypothesizing that grape-seed extract may be effective in reducing EI, while satiety is sustained.

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Subjects and methods

Subjects

Healthy nonsmoking men and women (aged 18–65 y, BMI 22–30 kg/m^2) living in the south of the Netherlands were recruited by advertisement in local newspapers. Potential subjects were roughly screened during a telephone call and were sent a subject information letter, the Herman–Polivy questionnaire (HP) (Herman *et al*, 1975; Herman & Polivy, 1980) and the Three Factor Eating Questionnaire (TFEQ) (Stunkard & Messick, 1985; Westerterp-Plantenga *et al*, 1999; Bond *et al*, 2001). Subjects were invited for a screening visit, during which final inclusion and exclusion criteria were checked. All subjects had to be relatively low to moderate in dietary restraint (factor 1 score <12) and had to have a low-to-moderate diet history (HP score <16). Furthermore subjects needed to be free from (eating) disorders, have a stable body weight (BW), not currently dieting, have no history of alcohol/drug abuse and not participating in another study. A total of 55 eligible subjects were asked for their written informed consent. Subjects were randomized over two treatment sequences (grape seed and placebo). Stratification took place for 1 gender, 2 BMI, 3 BW, 4 age and 5 TFEQ (factor 1 score). From the initial 55 subjects, 51 subjects eventually completed the whole experiment. Three subjects were not able to even start because of time problems and involvement in another trial. One subject had gastro-intestinal problems at the start of the study and she therefore had to quit.

Experimental design

The experiment had a double-blind, placebo-controlled, randomized, cross-over design. The experimental design consisted of two intervention periods of 3 consecutive days separated by a washout period of 3 weeks. During the first intervention period of 3 days, all subjects took the supplements three times daily, 30–60 min before breakfast, lunch and dinner. Supplements were administered as one tablet, both grape-seed and placebo tablets had the same shape, texture and color. The composition of the grape-seed tablets per day was 300 mg grape-seed extract (polyphenolics) containing $>90\%$ procyanidines, 1235.1 mg lactose and 264.9 mg cellulose. Placebo tablets contained only lactose and cellulose in the ratio 1482.1 mg/317.9 mg. During the 3 test days, a standard breakfast (one bottle milk and fruit orange and two bars Sultana Start) and a bag of snacks (sweet (Sultana forest fruit) and savory (TUC) cookies) were provided for at home. During the test days, the intake of drinks or snacks other than coffee and tea (without milk and sugar), water, fruit and the supplied snacks was not allowed. Subjects recorded in a diary the time of intake of the 'morning' supplement, possible side effects, intake of breakfast, snacks, possible intake of medication, intake of coffee, tea, etc, and intake of nonprescribed drinks, food or snacks. Subjects ate an *ad libitum* lunch and dinner in the University Laboratory Restaurant. Lunch consisted of a free choice between different filled rolls, and dinner was a choice between nasi, bami or French meat course (Iglo™). All meals were comparable in energy density (ED) and macronutrient composition (on average: breakfast ED: 2.7 kJ/g/day and macronutrient composition: 13/59/29 percentage of energy from protein, carbohydrate and fat (P/C/F), lunch ED: 3.0 kJ/g/day and macronutrient composition: 14/60/27 percentage of energy P/C/F, dinner ED: 2.7 kJ/g/day and macronutrient composition: 14/55/31 percentage of energy P/C/F). Subjects were asked before whether they liked the types of food offered, and they all confirmed that these foods were hedonically acceptable.

After a washout period of 3 weeks, subjects returned for the second intervention period, which was identical to the first intervention period, except for the change of supplement. They were asked not to change their daily activities or diet during the whole study period. On the test days, they were asked to eat until they would feel satiated. Subjects were also instructed to refrain from excessive alcohol intake (>3 glasses/day) during each intervention period, including the evening preceding each first test day. Subjects collected their supplement bottle, the first standard breakfast and the first bag with snacks the day preceding each intervention period. The subsequent breakfasts and snacks were provided on each day of the intervention period. Left-overs had to be brought back, every time subjects came to the laboratory.

The protocol was approved by the Ethics Committee of Maastricht University.

Anthropometry

Assessments during the screening visit included: measuring height using a wall-mounted stadiometer (Seca, model 220, Hamburg, Germany) and BW using a digital balance accurate to 0.02 kg. (Chyo-MW-150 K, Japan). Measurements were executed in underwear, after an overnight fast and after voiding the bladder. The body mass index (BMI) was calculated by BW/height^2 (kg/m^2).

Attitude towards eating

Eating behavior was analyzed during screening and each third test day, using a validated Dutch translation of the TFEQ (Stunkard & Messick, 1985; Westerterp-Plantenga *et al*, 1999). Cognitive restrained and unrestrained eating behavior (factor 1), emotional eating and disinhibition (factor 2) and the subjective feeling of hunger (factor 3) were scored. BW concern and chronic dieting behavior were investigated once during screening, using the HP questionnaire, which addresses weight consciousness (Herman & Polivy, 1980).

Appetite ratings

Appetite profile was determined from appetite ratings on 100 mm anchored visual analogue scales (VAS) (Westerterp-Plantenga *et al*, 1999), anchored with words expressing the most positive and most negative rating. Questions addressed hunger, fullness, appetite, satiety, thirst, prospective consumption and desire to eat. The appetite profile was assessed at six fixed time points: before breakfast (0800), before (1200) and after lunch (1300), before (1700) and after dinner

(1800) and at 2200 pm. For analyses, the mean of the six time points and over 3 days was calculated.

Hedonic value and sensory-specific satiety

During each test day, hedonic value of the lunch and dinner was determined using a single question on tastiness of the meal and scored on 100 mm anchored VAS (Westerterp-Plantenga *et al*, 2002). Sensory-specific satiety (Miller *et al*, 2000) was assessed at each test day for lunch and dinner as follows: at the first, as well as last bite of each roll during the lunch and at the first as well as at the last bite of the one-course dinner, subjects were asked about the pleasantness of taste in their mouth. This was scored on 100 mm anchored VAS. Sensory-specific satiety was expressed as the change in the actual pleasantness of taste over a course of a meal.

The mean over the two time points (lunch and dinner) and over 3 days was calculated and used for analyses.

Mood

Changes in mood during the intervention were scored on 100 mm anchored VAS at each third test day. Questions included relaxation, gloominess, pleasantness, anger, fright and sadness (Kovacs *et al*, 2001; Westerterp-Plantenga *et al*, 2002). The sum of the scores of the 'negative' feelings (gloominess, anger, fright and sadness) was calculated.

Tolerance

Tolerability of the study supplements was assessed at each third test day with a questionnaire on the occurrence of gastrointestinal and other complaints and scored on a 5-point scale (0=never, 1=rarely, 2=sometimes, 3=often, 4=very often) (Kovacs *et al*, 2001). The sum of the scores was calculated.

Energy requirement

The basal metabolic rate (BMR) was calculated using the Harris and Benedict Formula (Harris & Benedict, 1919). The physical activity level (PAL) was calculated using the computer simulation program 'Body weight'. The program requires the subject characteristics (age, gender, height and BW). It then calculates the most likely combination of EI and physical activity index at which BW remains stable (Westerterp *et al*, 1995; Westerterp-Plantenga *et al*, 1996). Energy requirement (ER) was calculated as BMR*PAL.

Statistics

Statistical analyses were performed with Statview SE Graphics™ for Macintosh. Values are expressed as mean± standard deviation (s.d.). Differences were considered significant at $P<0.05$.

EI (kJ/day), food intake (kg/day), ED (kJ/g/day) and macronutrient intake (g protein/day, g carbohydrate/day, g fat/day, g alcohol/day, % energy protein/day, % energy carbohydrate/day, % energy fat/day and % energy alcohol/day) were calculated for breakfast, lunch, dinner, snack intake in the morning, snack intake in the afternoon and snack intake in the evening. Analyses were performed with the means of the 3 test days. Differences in variables between the treatments were determined by analyses of variance for repeated measures (ANOVA), or Student's *t*-tests, where appropriate.

Based upon a frequency distribution, subjects ($n=51$) were catagorized into two groups: ER Low (who had an ER less than the median of 7.5 MJ/day) and ER Normal (who had an ER more than or equal to 7.5 MJ/day). To test the differences between these two groups, factorial ANOVA was applied on the following parameters: age, BMI, HP, BMR, PAL, 24 h EI, macronutrient composition and the scores on the different questionnaires.

Results

Characteristics of the subjects are shown in Table 1. There was no significant difference between EI (kJ/day) and food intake (kg/day) between the treatments, nor was there a difference in ED or macronutrient composition of food intake. The scores on the questionnaires TFEQ, hedonics, sensory-specific satiety, mood or tolerance were not significantly different between the two treatments (Table 2). The appetite and satiety ratings were measured at six time points during the day. Except for one parameter, there were no significant differences between the two treatments (data not shown). The only parameter that shows a significant difference is thirst before dinner ($P=0.05$). The grape-seed treatment shows significantly more thirst before dinner (45.1±24.2 mm VAS) than the placebo treatment (39.7±24.3 mm VAS). At the other five time points, thirst was not significantly different between the two treatments. Regression analysis showed no significant relationship between thirst and EI.

Table 1 Subject characteristics ($n=51$) at baseline

	Mean±s.d.	*Range*
Age (y)	48.7±14.3	18–64
Body Weight (kg)	74.9±11.0	53–99
BMI (kg/m^2)	25.6±2.6	21.5–30.5
TFEQ[a] (F1)	6.2±3.2	0–12
TFEQ (F2)	5.2±2.8	1–12
TFEQ (F3)	5.3±3.3	0–13
H–P[b]	12.2±3.4	4–16
Gender (m/f)	20/31	

[a]Three-factor eating questionnaire.
[b]Herman–Polivy questionnaire.

Table 2 Energy intake, food intake, macronutrient intake and scores on six questionnaires during the two treatments (n=51)

	Grape	*Placebo*	*P-Value*[a]
EI (MJ/day)	7.3±1.7[b]	7.4±1.8	NS[c]
Food intake (kg/day)	2.7±0.6	2.8±0.6	NS
Energy density (kJ/g/day)	2.7±0.6	2.7±0.7	NS
Protein (g/day)	59.0±12.7	58.6±12.5	NS
Carbohydrate (g/day)	269.8±67.2	273.4±70.0	NS
Fat (g/day)	45.5±11.1	45.6±11.0	NS
Macronutrient composition P/C/F (%)	14/63/24	14/63/24	NS
TFEQ[d] (F1)	6.6±4.0	7.3±4.0	NS
TFEQ (F2)	4.4±2.9	4.2±2.7	NS
TFEQ (F3)	5.1±3.8	4.5±3.6	NS
Satiety (mm VAS)	52.2±16.6	54.5±17.8	NS
Hedonic value (mmVAS)	62.3±16.3	60.7±17.3	NS
SSS[e] (Δ mm VAS)	2.9±12.2	2.7±11.1	NS
Mood (mm VAS)	143.3±31.9	141.6±34.4	NS
Tolerance	6.3±5.3	5.3±5.0	NS

[a]Indicates the results of ANOVA repeated measures for the differences between the two treatments.
[b]Mean±s.d.
[c]NS: Not significant.
[d]Three-factor eating questionnaire.
[e]Sensory-specific satiety.

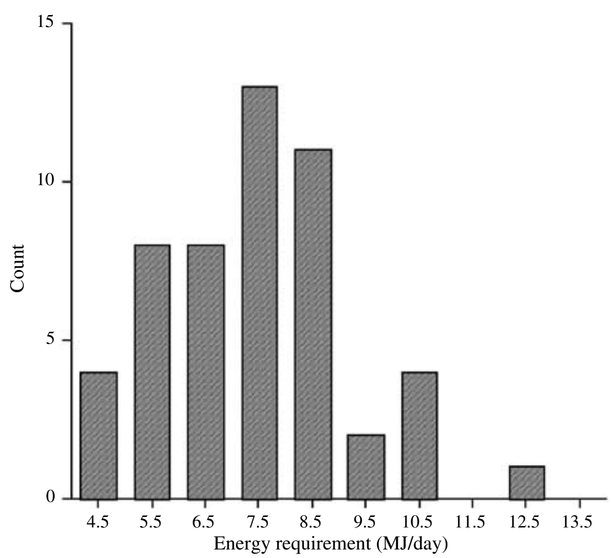

Figure 1 Frequency distribution of the energy requirements (MJ/day) of all the subjects. The median is at 7.5 MJ/day.

The frequency distribution of energy requirement (ER) (Figure 1) shows that subjects' ER varied from 4 to 13 MJ, with a median of 7.5 MJ/day. Possible treatment effects were tested in two subgroups separated by the median, ER<7.5 and ER≥7.5 MJ/day (Table 3). The subgroup characteristics differed in terms of BMR, PAL, 24 h EI, F1 score (TFEQ), F3 score (TFEQ) and hedonic value score. The group with

Table 3 Subject characteristics, energy intake, macronutrient intake and scores on six questionnaires for the ER<the median *vs* ER≥the median (7.5 MJ/day) group

	ER<the median (n=28)	*ER≥the median (n=23)*	*P-Value*[a]
Age (y)	50.8±13.5[b]	46.3±15.1	NS[c]
Gender (f/m)	24/4	7/16	
BMI (kg/m^2)	25.7±2.8	25.6±2.4	NS
H–P[d]	12.8±3.2	11.5±3.5	NS
BMR (MJ/day)	6.0±0.8	7.0±0.8	<0.01
PAL[e]	1.0±0.2	1.3±0.1	<0.01
EI (MJ/day)	6.2±1.0	8.9±1.3	<0.01
Macronutrient composition P/C/F (%)	14/63/24	14/63/24	NS
TFEQ[f] (F1)	7.1±3.7	6.1±3.6	0.06
TFEQ (F2)	5.2±2.9	4.7±2.8	NS
TFEQ (F3)	5.6±3.6	4.8±3.0	0.05
Satiety (mm VAS)	54.0±17.6	58.6±19.0	NS
Hedonic value (mm VAS)	56.9±15.6	67.1±16.6	0.03
SSS[g] (Δ mm VAS)	2.5±10.5	3.2±12.7	NS
Mood (mm VAS)	145.4±35.8	138.9±26.8	NS
Tolerance	6.3±5.3	5.2±4.7	NS

[a]Indicates the results of factorial ANOVA for the differences between the two treatments.
[b]Mean±s.d.
[c]NS: Not significant.
[d]Herman-Polivy questionnaire.
[e]Physical activity level.
[f]Three-factor eating questionnaire.
[g]Sensory-specific satiety.

ER<the median had a lower BMR, a lower PAL, a lower EI, a trend for a higher F1 score, a higher F3 score and a lower score on hedonic value compared to the group with ER≥the median. Multiple regression analysis showed that the reduced EI in the group with ER≥the median was not related to BMR, PAL, F1, F3 or hedonics (data not shown).

To assess if there were differences with respect to the treatments within the two groups, analyses were carried out for the two groups (ER< or≥the median) separately. In the ER≥the median group, EI during grape-seed treatment was lower than during placebo treatment (Table 4). Meanwhile, macronutrient composition, TFEQ scores, satiety scores (Table 5), hedonic values and changes in pleasantness of taste were not affected. Also, mood and tolerance were not affected when using the grape-seed supplements. There was no difference found in the ER<the median group in EI between the grape-seed treatment compared to the placebo condition (Table 6), nor was there any difference found in macronutrient composition, TFEQ scores, satiety, hedonic values, pleasantness of taste and mood scores. The tolerance of the subjects from the ER < the median group was less when using the grape seed instead of placebo (nausea, headache and tiredness: 7.3±5.3 *vs* 5.3±5.3, $P<0.05$).

In order to exclude that the effect of grape seed in the ER≥the median group could be a gender effect, we analyzed the men and women separately. Although the women ate significantly less than the men (6.7±1.4 *vs* 8.5±1.6 MJ/day,

Table 4 Energy intake, macronutrient composition and scores on six questionnaires of the ER ≥ the median group (n=23) during the two treatments

	Grape	*Placebo*	*P-Value*[a]
EI (MJ/day)	8.5 ± 1.4[b]	8.9 ± 1.3	0.05
Macronutrient composition P/C/F (%)	14/63/24	14/63/24	NS[c]
TFEQ[d] (F1)	6.0 ± 3.6	6.7 ± 3.8	NS
TFEQ (F2)	4.3 ± 2.7	4.1 ± 2.9	NS
TFEQ (F3)	5.2 ± 3.6	4.8 ± 3.8	NS
Satiety (mm VAS)	50.0 ± 17.0	48.6 ± 16.5	NS
Hedonic value (mm VAS)	67.9 ± 16.1	66.5 ± 16.7	NS
SSS[e] (Δ mm VAS)	4.0 ± 11.8	2.4 ± 12.7	NS
Mood (mm VAS)	139.7 ± 26.8	138.0 ± 28.7	NS
Tolerance	5.1 ± 5.1	5.3 ± 4.7	NS

[a]Indicates the results of ANOVA repeated measures for the differences between the two treatments.
[b]Mean ± s.d.
[c]NS: Not Significant.
[d]Three-factor eating questionnaire.
[e]Sensory-specific satiety.

Table 5 Scores of seven appetite-related parameters (100 mm VAS) completed at six fixed time points a day (mean ± s.d.) of the ER ≥ the median group (n=23) during the two treatments

	Grape	*Placebo*	*P-Value*[a]
Hunger	36.2 ± 19.0	36.9 ± 18.6	NS
Fullness	47.2 ± 18.0	45.3 ± 17.1	NS
Appetite	40.8 ± 18.8	39.1 ± 18.4	NS
Satiety	50.0 ± 17.0	48.6 ± 16.5	NS
Thirst	41.2 ± 26.6	38.0 ± 25.5	NS
Amount	44.2 ± 20.0	43.6 ± 18.6	NS
Desire to eat	39.9 ± 19.7	39.4 ± 18.4	NS

[a]NS: Not significant.

$P<0.01$), there was no gender effect in grape-seed-affected EI (24 h EI grape seed *vs* placebo, men: 8.5 ± 1.6 *vs* 8.5 ± 1.6 MJ/day, women: 6.5 ± 1.2 *vs* 6.7 ± 1.4 MJ/day). Also, the scores on the questionnaires TFEQ, satiety, hedonic value, pleasantness of taste, mood and tolerance did not differ significantly between men and women.

Discussion

In the present study, the potential effect of grape seed on EI and macronutrient composition of food intake was investigated in normal to overweight men and women, taking attitude towards eating, appetite ratings, hedonics, sensory-specific satiety, mood and tolerance into account. Grape seed appeared to be effective in reducing EI in normal to overweight subjects with an energy requirement ≥ the median of 7.5 MJ/day. Their EI in the placebo condition was 8.9 ± 1.3 MJ/day, and in the grape-seed condition 8.5 ± 1.4 MJ/day. The effect was not significantly present in the total sample, probably due to the very low EI of many subjects. The energy requirement of the subjects in this study varied from 4 to 13 MJ/day. Half of the subjects needed less than 7.5 MJ/day. These subjects had a significantly lower BMR, a lower PAL, tended to be more dietary restraint and had more feelings of hunger (F3 score) compared to the subjects with an ER ≥ the median of 7.5 MJ/day. The lower BMR and PAL values can be explained by the fact that the ER < the median group consisted of mainly women (24 out of 28), and the ER ≥ the median group consisted of mainly men (16 out of 23). Women naturally have a lower BMR than men (Westerterp-Plantenga *et al*, 1994). The negative effect that grape-seed supplementation in this group had on tolerance may have affected their hedonic evaluation. It is likely that the decrease in tolerance is also a factor in the decreased EI. However, regression analysis showed that EI in the ER < the median group was not related to tolerance or hedonics. As a result of the fact that they ate little, they probably had more feelings of hunger. We conclude that grape seed was not effective on 24 h EI, while ER and subsequently EI were very low. With a low EI it may be unlikely to reduce EI even further. A realistic minimum of EI may be required to be reduced, and not an already very low EI.

Table 6 Energy intake, macronutrient composition and scores on six questionnaires of the ER < the median group (n=28) during the two treatments

	Grape	*Placebo*	*P-Value*[a]
EI (MJ/day)	6.3 ± 1.1[b]	6.2 ± 1.3	NS[c]
Macronutrient composition P/C/F (%)	14/62/24	14/62/24	NS
TFEQ[d] (F1)	7.1 ± 4.3	7.8 ± 4.1	NS
TFEQ (F2)	4.5 ± 3.2	4.2 ± 2.6	NS
TFEQ (F3)	5.0 ± 3.9	4.3 ± 3.5	NS
Satiety (mmVAS)	37.6 ± 15.5	34.0 ± 14.6	NS
Hedonic value (mmVAS)	57.5 ± 15.2	55.6 ± 16.5	NS
SSS[e] (Δ mmVAS)	2.1 ± 12.6	3.0 ± 9.7	NS
Mood (mmVAS)	146.2 ± 35.8	144.5 ± 38.7	NS
Tolerance[f]	7.3 ± 5.3	5.3 ± 5.3	0.02

[a]Indicates the results of ANOVA repeated measures for the differences between the two treatments.
[b]Mean ± s.d.
[c]NS: Not significant.
[d]Three-factor eating questionnaire.
[e]Sensory-specific satiety.
[f]Includes: nausea, headache and tiredness.

In addition to studies on grape-seed effects on body weight in rats, this is the first human study investigating the effect of grape seed on EI. A study in rats found that rats consuming grape-seed tannins gained less weight than the control animals (Tebib *et al*, 1996). A delayed absorption and a lower digestibility of the diet resulting from grape-seed tannins were discussed as possible reasons for this lower weight gain. However, we did not observe tolerance effects related to a lower digestibility. Another study in rats showed that grape seed reduced food intake without major changes in metabolism (Wielinga *et al*, 2002). The underlying mechanism could be an increased lipolysis. Ardevol *et al* (2000) found the same result *in vitro*, only by incubating 3T3-L1 cells with grape seed, lipolysis was favored and biosynthesis inhibited, thus degrading fat stores.

The mechanism of grape seed in the short term could be, as Tebib also suggested, a delayed absorption of the diet, which might support sustained satiety while subjects ingest less food.

Taken together, in subjects with an ER ≥ the median of 7.5 MJ/day, subjects' 24 h EI after ingestion of grape seed decreased from 8.9 to 8.5 MJ/day. This corresponds with a decrease in EI of on average 4%. A decrease of 4% might have a long-term consequence for BW regulation (Westerterp *et al*, 1995). However, whether effects of long-term use of grape seed will be compensated for, cannot be predicted. A simple calculation shows that if the EI reduction in the present study of ~352 kJ/day would continue for 1 y (125.3 MJ in total), this would result in a weight loss (or prevention of weight gain) of 3.7 kg, when one assumes that an average of 34 MJ is required to make 1 kg body tissue (containing a combination of fat mass and fat-free mass) (Forbes *et al*, 1986; Raben *et al*, 2002), when all other factors are held the same. Thus, if grape seed would decrease EI by 4% whole year long, it would prevent weight gain or can be useful in helping people lose weight.

24 h EI is hard to measure reliably, especially in obese subjects (Roberts *et al*, 1998; Seidell, 1998). Under-reporting of food intake is a very common problem (Schoeller & Seidell, 1990; Johnson *et al*, 1994; Goris *et al*, 2000, 2001). In this study, we tried to skirt around these problems of misreporting by using a different design. Subjects came to the laboratory restaurant for lunch and for dinner, where the exact amount of food eaten was weighed. Standardized breakfasts and snacks were provided for at home. With this design, we were able to calculate subjects' EI very accurately. Food intake was measured during 3 consecutive days, which was to the benefit of the possibly longer-term effect of grape seed. Compared to preload studies, this design assesses both the effects of grape seed postprandially and postabsorptively as well as the effect at different points of time a day.

We believe that the present data are useful to develop further research on this topic. Long-term assessment of the effects of grape-seed extract on BW regulation in subjects with a normal energy requirement, taking the possible mechanism of increased lipolysis into account, is recommended.

Conclusion

In subjects with an energy requirement ≥ the median of 7.5 MJ/day grape-seed extract affected 24 h EI with on average 4% (P=0.05), without affecting satiety or other variables. In subjects showing decreased tolerance and a limited EI, grape seed did not affect 24 h EI. We conclude that grape seed could be effective in reducing 24 h EI in normal to overweight dietary unrestrained subjects of 18–65 y age range with an energy requirement ≥ 7.5 MJ/day, while satiety was sustained.

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