Sensory-specific satiety in obese and normal-weight women

Harriëtte M Snoek, Linda Huntjens, Leo J van Gemert, Cees de Graaf, and Hugo Weenen

ABSTRACT

Background: Sensory-specific satiety has been found to play an important role in food choice and meal termination, and it might be a factor contributing to obesity.

Objective: We hypothesized that obese and normal-weight people have different sensitivities to sensory-specific satiety for high-fat foods.

Design: Sensory-specific satiety was measured in 21 obese (x body mass index (BMI; in kg/m²): 33.1) and 23 normal-weight (BMI: 22.8) women who were matched for restrained eating behavior, physical activity, age, and smoking behavior. Food intake, appetite ratings, and liking scores before and after an ad libitum lunch were measured. Products differed in fat content and taste (ie, low-fat sweet, low-fat savory, high-fat sweet, and high-fat savory), and the subjects tested all 4 products. In the first study, sandwiches were tested; in the second study, snacks were tested.

Results: Sensory-specific satiety for all products was observed in both subject groups. No significant differences were observed between the obese and normal-weight subjects in either sensory-specific satiety or food intake for any of the products or product categories tested. Taste (sweet or savory) had a significantly (P < 0.05) stronger effect on sensory-specific satiety than did fat content. Appetite ratings strongly decreased after lunch, and appetite for a meal or snack after lunch was significantly higher in obese than in normal-weight subjects, whereas scores before lunch did not differ significantly.

Conclusions: Obese and normal-weight people do not differ in their sensitivity to sensory-specific satiety, and factors other than fat content have the greatest effect on sensory-specific satiety. Am J Clin Nutr 2004;80:823–31.

KEY WORDS Sensory-specific satiety, obesity, overweight, fat-specific satiety, appetite, taste

INTRODUCTION

Obesity results from a long-term positive energy balance—ie, the energy intake is greater than the energy expenditure. Energy or food intake is regulated by, among other factors, subject factors (eg, appetite, satiation or satiety, and self-inhibition) and product factors (eg, hedonic value and variety) (1–3). Under experimental conditions, the intake of a single food relative to the intake of other foods is strongly affected by sensory-specific satiety. This phenomenon was first observed in monkeys and was found to be reflected in the change in the response of hypothalamic neurons: the response stops when the monkey is exposed to the sight and taste of foods on which the monkey has fed to satiety, whereas the neurons continue to respond to other foods (4). Sensory-specific satiety has been defined as the decrease in pleasantness of a product after it is eaten compared with the decrease in the pleasantness of products that were tasted but not eaten to satiety. For example, after eating sausages, the liking of the sausages strongly declined at the same time that liking of other savory products declined less, and the liking of sweet foods such as cookies even increased (2). The decrease in liking is also associated with a lower intake of that particular food in a second course. Sensory-specific satiety occurs within 2 min after consumption, when there has been little opportunity for digestion and absorption, and it is specific for the sensory aspects of products (2, 5, 6).

Knowledge of the required amount of food eaten to reach sensory-specific satiety is limited. Texture, flavor, and color have been described as important factors affecting the degree of sensory-specific satiety (3, 6). There is also evidence of the influence of macronutrients on sensory-specific satiety (7–11). A clear effect of higher sensory-specific satiety was observed only for foods that are high in protein (7, 10, 12), and a trend for higher sensory-specific satiety was found for products high in sweet carbohydrates (13, 14) and fatty acids (15).

A high intake of energy from overeating of high-fat products is the result of the high energy density, high palatability, and weak satiation of high-fat foods (16–21). The results of various studies have suggested that obese subjects show a greater preference for high-fat foods than do normal-weight subjects (22–24). In addition, interindividual differences in sensory-specific satiety could very well contribute to differences in food intake. Differences in sensory-specific satiety have been found in subjects with eating disorders (25) and between different age groups (26). The results of a study by Epstein et al (27) suggest that obese women may be less sensitive to sensory-specific satiety than are normal-weight women. In that study, obese women showed a smaller decline in salivary flow than did normal-weight women after repeated exposure to palatable food cues. In a cross-sectional study by McCorry et al (28), obese subjects consumed a greater variety of energy-dense foods than did normal-weight...
subjects, whereas normal-weight subjects consumed a greater variety of low-energy-dense foods than did obese subjects. If sensory-specific satiety for high-fat foods is less in obese subjects than in normal-weight subjects, that could be an important factor in the development of overweight (1).

In this study, obese and normal-weight women were exposed to either low-fat sweet, low-fat savory, high-fat sweet, or high-fat savory products, according to a repeated within-subject design. Thus, it could be ascertained whether sensory-specific satiety for high-fat foods differed between obese and normal-weight subjects.

SUBJECTS AND METHODS

Two experiments are reported here, one in which sandwiches were eaten, and one in which snacks were eaten. The experiments were identical in design and procedure; only the products were different.

Subjects

The number of subjects in the sandwich and snack experiments was 44 and 43, respectively; all were healthy women living in or near Zeist, Netherlands. They were selected from a pool of 1500 volunteers. Exclusion criteria for the study were age < 18 or > 65 y, dieting, consumption of > 21 servings of alcohol/wk, diabetes, an unwillingness to eat or an allergy to the test foods, and the use of medication with a possible effect on taste, appetite, or both (eg, antidepressives). Allowed medications were contraceptives, cholesterol- and hypertension-reducing medication, diuretics, painkillers, and medication for asthma and disorders of the bronchial tubes. Because an insufficient number of obese men were available, only women were selected. Obese women (BMI ≥ 30) were matched with normal-weight women (BMI 20–25) for age, smoking behavior, physical activity level, and score on the restrained-eating questionnaire (29). Two subjects were unable to complete the study. Basic anthropometric data on the participating subjects are shown in Table 1. Subjects were told that the study was about the relation between (over)weight and taste. Each subject gave written informed consent. The procedures followed were in accordance with the ethical standards on human experimentation of the Netherlands Organization for Applied Scientific Research TNO. Forty-three of the 46 subjects in the sandwich experiment also participated in the snack experiment. Two additional subjects were recruited for the snack experiment by using the same selection and matching criteria.

Design

The design of this study was similar to that of other sensory-specific satiety studies. Subjects came to the laboratory, rated their appetite on 6 different scales, tasted and rated foods with respect to pleasantness of the taste, ate one particular food ad libitum, tasted and rated the same foods again, and rated their appetite again (Table 2). Each subject came 4 times and tested all 4 products once. Both the order of serving lunches and the order of rating were randomized across and within subjects. The products varied in taste (sweet or savory) and fat content (low-fat or high-fat).

Foods

In both experiments, 4 products were served according to a 2 × 2 factorial design. The first factor was taste (sweet or savory), and the second factor was fat content (low-fat or high-fat) (Table 3). Products were prepared the morning of consumption and served at room temperature. Table 3 shows the weight of the rating set and lunch servings and the energy and nutrient contents per 100 g test food. Nutrient composition was calculated according to the Dutch nutrient database (30).

Sandwich experiment

Sandwiches were prepared with 4 different fillings, which a pilot study found that subjects liked approximately equally. Sandwiches were prepared with 2 slices of whole-wheat bread and 35 g of either white chocolate spread (Albert Heijn, Zaan-dam, Netherlands), rose hip jam (Albert Heijn, pâte (Albert

### Table 1

<table>
<thead>
<tr>
<th>Group</th>
<th>Age</th>
<th>Height</th>
<th>Weight</th>
<th>BMI</th>
<th>Restraint eating questionnaire score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandwich experiment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal-weight subjects</td>
<td>46 ± 10</td>
<td>1.68 ± 0.07</td>
<td>64 ± 6.3</td>
<td>22.8 ± 1.42</td>
<td>2.72 ± 0.68</td>
</tr>
<tr>
<td>Obese subjects</td>
<td>47 ± 11</td>
<td>1.68 ± 0.06</td>
<td>93 ± 8.7</td>
<td>33.1 ± 1.29</td>
<td>2.76 ± 0.23</td>
</tr>
<tr>
<td>Snack experiment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal-weight subjects</td>
<td>47 ± 9</td>
<td>1.69 ± 0.07</td>
<td>65 ± 6.5</td>
<td>22.8 ± 1.39</td>
<td>2.70 ± 0.71</td>
</tr>
<tr>
<td>Obese subjects</td>
<td>47 ± 10</td>
<td>1.68 ± 0.06</td>
<td>93 ± 8.4</td>
<td>32.9 ± 1.93</td>
<td>2.69 ± 0.74</td>
</tr>
</tbody>
</table>

1. All values are x ± SD. The number of smokers per group was n = 5 (normal-weight) and 6 (obese) in the sandwich experiment and n = 4 (normal-weight and 5 (obese) in the snack experiment.
2. Dutch Eating Behavior Questionnaire, which uses a 5-point scale from 1 (low) to 5 (high) (29).
3. Significantly different from normal-weight subjects, P < 0.001 (t test).
Heijn), or roast beef (Albert Heijn) (for composition, see Table 3). Bread crusts were removed, and sandwiches were cut in 4 pieces. The sandwiches were offered on plastic trays containing 2 pieces of sandwich each (total: ≈36 g). For the pleasantness ratings before and after the lunch, subjects were presented with a small piece (1/8 of a sandwich) of each of the 4 sandwiches.

### Snack experiment

The 4 test products in the snack experiment were a chocolate candy bar (Mars Bar; Masterfoods, Veghel, Holland), pears in light syrup (Del Monte International, Staines, United Kingdom), cheese crackers (Van Kooten, Veenendaal, Netherlands), and fillet of chicken (Albert Heijn). Candy bars were cut in 6 pieces (the ends were removed); the pears and the fillet of chicken were cut in pieces weighing ≈5 g. Each product was presented on a plate in large amounts: 4 chocolate candy bars (≈212 g), 150 g cheese crackers, 350 g pear pieces (without the syrup), or 300 g fillet of chicken (Table 3). When subjects finished the food, they could ask for more, but only a few subjects did so. The pleasantness ratings, the stimuli consisted of 1/8 of a candy bar, one piece of pear, one piece of chicken, and one cheese cracker.

### Procedure

In both experiments, subjects came to the institute for lunch at 1200 or 1300 on Tuesdays, Wednesdays, or Thursdays. All subjects came 4 times during the 5 wk of the study, with at least 5 d between the sessions. Subjects were instructed to eat a normal breakfast; to eat nothing between breakfast and lunch to drink only water, tea, or coffee; and to have no unusual physical activity on the day of an experiment. The test took ≈40 min; subjects were seated in private booths and were not allowed to talk, read, or smoke during the experiment. Water was available throughout the experiment, but its intake was not measured.

Subjects first rated their appetite on six 150-mm visual analogue scales anchored with “weak” and “strong” on the left and right sides, respectively. Specifically they were asked to rate their “appetite for a meal,” “appetite for something sweet,” “appetite for something savory,” “over-satiety (over-fullness),” “[feelings of being] feeble, weak with hunger,” and “appetite for a snack.” After the appetite ratings, subjects tasted and rated the pleasantness of each of the 4 products on a 7-point hedonic scale (very unpleasant to very pleasant, with neither unpleasant nor pleasant in the middle). The pieces of the foods were given one after another, and, for each serving, subjects were given a separate response form, so that they could not compare the current rating with previous ratings. The participants were instructed to take a bite of the sample and to keep the bite in their mouth while rating the food. Subjects swallowed the food when the rating was completed.

After rating, subjects were given one of the 4 products ad libitum for lunch. They were instructed to eat until they reached satiety. Subjects came at lunchtime in the snack experiment as well as in the sandwich experiment, and they were asked to eat to satiety and to consider the offered snacks as lunch, although, in the snack experiment, those were products not commonly eaten for lunch.

In the sandwich experiment, subjects were offered 4 trays at a time (containing 2 pieces of sandwich each, ≈36 g); after a few minutes, empty trays were replaced with full ones, even when there were still a few full trays left. This was repeated until the subject indicated he or she was satiated. In the snack experiment, those were products not commonly eaten for lunch.

As soon as subjects had finished lunch, they re-rated the 4 test pieces and also re-rated the appetite scales. Each subject received 1 of the 4 products for lunch in each of the 4 sessions; the order in which the 4 products were served and the order in which they were rated before and after lunch were randomized across and within subjects.

### Statistical analysis

First, we calculated the mean liking ratings on the 7-point hedonic scale for each of the tasted foods, before and after lunch.

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**Table 3**

<table>
<thead>
<tr>
<th>Product</th>
<th>Weight of rating piece</th>
<th>Weight of serving</th>
<th>Energy</th>
<th>Protein</th>
<th>Fat</th>
<th>CHO</th>
<th>Fiber</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g</td>
<td>g</td>
<td>kJ/100 g test food</td>
<td>g/100 g test food</td>
<td>g/100 g test food</td>
<td>g/100 g test food</td>
<td>g/100 g test food</td>
</tr>
<tr>
<td>Sandwiches</td>
<td>36</td>
<td>144²</td>
<td>1013</td>
<td>9.5</td>
<td>2.3</td>
<td>45.1</td>
<td>5.1</td>
</tr>
<tr>
<td>Bread</td>
<td>5.5²</td>
<td>88</td>
<td>1013</td>
<td>9.5</td>
<td>2.3</td>
<td>45.1</td>
<td>5.1</td>
</tr>
<tr>
<td>High-fat filling</td>
<td>3.5</td>
<td>56</td>
<td>2500</td>
<td>2.0</td>
<td>41.0</td>
<td>56.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Chocolate spread</td>
<td>3.5</td>
<td>56</td>
<td>1569</td>
<td>11.0</td>
<td>35.5</td>
<td>4.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Pâté</td>
<td>3.5</td>
<td>56</td>
<td>1060</td>
<td>2.0</td>
<td>0.5</td>
<td>60.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Low-fat filling</td>
<td>3.5</td>
<td>56</td>
<td>704</td>
<td>28.3</td>
<td>5.7</td>
<td>0.8</td>
<td>0.0</td>
</tr>
<tr>
<td>Rose hip jam</td>
<td>3.5</td>
<td>56</td>
<td>704</td>
<td>28.3</td>
<td>5.7</td>
<td>0.8</td>
<td>0.0</td>
</tr>
<tr>
<td>Roast beef</td>
<td>3.5</td>
<td>56</td>
<td>704</td>
<td>28.3</td>
<td>5.7</td>
<td>0.8</td>
<td>0.0</td>
</tr>
<tr>
<td>Snacks</td>
<td>&lt;30</td>
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<tr>
<td>High-fat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chocolate candy bar</td>
<td>9</td>
<td>212</td>
<td>1871</td>
<td>3.6</td>
<td>17.3</td>
<td>68.9</td>
<td>1.0</td>
</tr>
<tr>
<td>Cheese crackers</td>
<td>9</td>
<td>150</td>
<td>2368</td>
<td>15.0</td>
<td>38.0</td>
<td>41.0</td>
<td>1.9</td>
</tr>
<tr>
<td>Low-fat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pears in light syrup</td>
<td>5</td>
<td>350</td>
<td>272</td>
<td>0.3</td>
<td>0.1</td>
<td>15.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Fillet of chicken</td>
<td>5</td>
<td>300</td>
<td>667</td>
<td>30.9</td>
<td>3.8</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

¹ CHO: carbohydrate.
² Total weight of the 4 pieces (4× 1/8 sandwich).
³ Four plastic trays of 36 g each; ad libitum amount available.
Sensory-specific satiety was assessed by comparing the decrease in liking (score after lunch–score before lunch) of the eaten foods with the mean decrease in liking of the uneaten foods. A paired t test for each of the foods was used to determine whether the sensory-specific satiety effect was significant.

Next, the decrease in liking of the eaten food was compared with the decrease in liking of the uneaten foods in the obese and normal-weight groups separately, and this process was followed for each food consumed at lunch. The effect of weight status (obesity or normal weight) on sensory-specific satiety was analyzed by analysis of variance (ANOVA), with weight status as a between-subjects factor and products as a within-subject factor. Persons were nested within groups (overweight and normal-weight). To determine whether obesity had a differential effect for each of the foods consumed at lunch. The effect of weight status (obesity or normal weight) on sensory-specific satiety was analyzed by analysis of variance (ANOVA), with weight status as a between-subjects factor and products as a within-subject factor. Persons were nested within groups (overweight and normal-weight). To determine whether obesity had a differential effect on the products eaten (chocolate spread, rose hip jam, pâté, roast beef) and dissimilar (jam and roast beef) to satiety for lunch (n = 44). The decline in pleasantness of the taste of eaten products was significantly larger than the decline of uneaten products for chocolate spread (P < 0.001), rose hip jam (P = 0.002), and pâté (P < 0.001) and was of borderline significance for roast beef (P = 0.052).

Average decreases in the “similar in taste” and “similar in fat content” products were therefore compared with the use of a t test.

Appetite ratings were determined by measuring (in mm) the ratings on the 150-mm line scale. The ANOVA of the appetite ratings was done with the factor time (with 2 levels, ie, before and after lunch) and obesity as main factors and time × obesity as the interaction factor.

Significance in all tests was set at P < 0.05. All data analyses were performed with the use of EXCEL for WINDOWS software (version 7.0; Microsoft Corp, Redmond, WA) and SPSS software (version 10.1; SPSS Inc, Chicago).

RESULTS

Sandwich experiment

All lunches induced sensory-specific satiety, because the decline in pleasantness of the taste was greater for the eaten than the uneaten products. This difference in decline was significant for chocolate spread, rose hip jam, and pâté and borderline significant for roast beef (P = 0.052). The initial and postlunch average pleasantness ratings per product are shown in Figure 1.

The decline in pleasantness per product and per group of subjects is shown in Figure 2. Sensory-specific satiety was found in both groups, but no differences were found between obese and normal-weight subjects. Significant effects were found for the taste × fat interaction, which refers to the notion that there was little difference between chocolate spread and jam scores and greater difference between pâté and roast beef scores. No significant interactions with obesity were found. The difference in decline was significantly (P = 0.020) greater (and thus sensory-specific satiety was higher) for products rich in fat (chocolate spread and pâté) and lower for products low in fat (rose hip jam and roast beef).

The effect of taste and fat content on sensory-specific satiety is shown in Figure 3. The product eaten for lunch declined most
in pleasantness. Products similar to lunch in taste (sweet or savory) declined more than did products different from the lunch product, whereas products similar in fat content declined less than did the other products. Overall, taste seemed to determine sensory-specific satiety more than fat content. The decline in pleasantness was greater for products similar to lunch in taste than for products similar to lunch in fat content.

Food intake

The average intake of the ad libitum lunch per product for obese and normal-weight subjects is shown in Table 4. Intakes did not differ significantly between the groups. Intake was correlated to the initial liking (score on pleasantness of the taste before lunch) of the product ($r = 0.222$, $P = 0.003$). However, there was no correlation between intake and any of the appetite ratings.

Appetite ratings

After the ad libitum lunch intake, subjects reported a strong decrease in “appetite for a meal,” “appetite for something sweet,” “appetite for something savory,” “[feelings of] feeble, weak with hunger,” and “appetite for a snack.” There was a strong increase in “over-satiety (overfull).” After a sweet meal, “appetite for something sweet” decreased more than it did after a savory meal ($P < 0.05$), and “appetite for something savory” decreased more after a savory than after a sweet meal ($P < 0.001$). Obese subjects had significantly higher after-lunch ratings for “appetite for a meal” and “appetite for a snack” than did normal-weight subjects, whereas scores before lunch did not differ significantly (Figure 4). All other after-lunch ratings were not significantly different between obese and normal-weight respondents (not shown in figures). In an ANOVA, we found a significant main effect for time and borderline significant effect

### TABLE 4

<table>
<thead>
<tr>
<th>Intake</th>
<th>Chocolate spread</th>
<th>Rose hip jam</th>
<th>Pâté</th>
<th>Roast beef</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(g)</td>
<td>(kJ)</td>
<td>(g)</td>
<td>(kJ)</td>
<td>(g)</td>
</tr>
<tr>
<td>Obese subjects, $n = 21$</td>
<td>118 ± 63</td>
<td>100 ± 51</td>
<td>129 ± 69</td>
<td>142 ± 95</td>
<td>123 ± 72</td>
</tr>
<tr>
<td>(g)</td>
<td>1631</td>
<td>1022</td>
<td>1586</td>
<td>1732</td>
<td>1511</td>
</tr>
<tr>
<td>Normal-weight subjects, $n = 23$</td>
<td>111 ± 54</td>
<td>120 ± 63</td>
<td>132 ± 46</td>
<td>122 ± 41</td>
<td>121 ± 51</td>
</tr>
<tr>
<td>(g)</td>
<td>1534</td>
<td>1227</td>
<td>1622</td>
<td>1488</td>
<td>1468</td>
</tr>
<tr>
<td>Total subjects, $n = 44$</td>
<td>114 ± 58</td>
<td>111 ± 58</td>
<td>131 ± 58</td>
<td>132 ± 72</td>
<td>122 ± 62</td>
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<tr>
<td>(g)</td>
<td>1576</td>
<td>1135</td>
<td>1610</td>
<td>1610</td>
<td>1483</td>
</tr>
</tbody>
</table>

*No significant differences were observed between obese and normal-weight subjects (t test).*
for obesity \((P = 0.065)\), but the interaction effect was not significant \((P = 0.177)\).

Snack experiment

After all snacks, sensory-specific satiety was observed. The decline in pleasantness of the taste of eaten products was significantly larger than that of uneaten products for chocolate candy bar, pears in light syrup, cheese crackers, and fillet of chicken. Initial liking scores (before lunch) differed significantly between the products \((P = 0.05)\) but there were no differences in liking between obese and normal-weight subjects. The initial and postlunch average pleasantness ratings per product are shown in Figure 5, and the decline in pleasantness of taste among each group of subjects is shown in Figure 6. Sensory-specific satiety was found in both groups, but no differences were found between obese and normal-weight subjects. No significant interactions were found between taste, fat content, and obesity.

The effect of both factors (taste and fat content) on sensory-specific satiety are shown in Figure 7. Products similar in taste to lunch declined more in pleasantness of taste (ie, liking) than did products different from the lunch product, whereas the opposite was true for fat content. Overall taste (sweet or savory) seemed to determine sensory-specific satiety more than did fat content; products similar to lunch in taste declined more in liking than did products similar to lunch in fat content (Figure 7).

Food intake

The average intake during the ad libitum lunch per product for obese and normal-weight subjects is shown in Table 5. No significant difference in intakes was found between the groups, although intake tended to be higher for obese subjects for all products except cheese crackers (Table 5). Intake was correlated to the initial liking (score on pleasantness of the taste before lunch) of the product \((r = 0.217, P = 0.005)\) and to the appetite ratings “appetite for a meal” \((r = 0.152, P = 0.045)\) and “appetite for a snack” \((r = 0.169, P = 0.029)\).

Appetite ratings

After the ad libitum lunch intake, subjects reported a strong decrease in appetite for a meal, appetite for something sweet, appetite for something savory, feelings of being feeble and weak with hunger, and appetite for a snack. There was a strong increase in over-satiety (being overfull). Appetite for something sweet decreased significantly more after a sweet meal than after a savory meal, and appetite for something savory decreased significantly more after a savory meal than after a sweet meal (both: \(P < 0.001\)). The after-lunch scores of obese subjects were significantly lower for over-satiety \((P = 0.005)\) and significantly higher for appetite for a meal, appetite for a snack, and appetite for something savory (all: \(P = 0.026\) (Figure 8; not all data shown). Before lunch, only the average score for overshatiety was significantly higher in obese than in normal-weight subjects. In

![FIGURE 4](image_url)

**FIGURE 4.** Mean (±SEM) ratings per group on two 15-cm visual analogue scales anchored by weak (0) and strong (15) scores for appetite for a meal (A) and appetite for a snack (B) before (□) and after (●) ad libitum lunch of sandwiches \((n = 44)\). There was a significant time effect \((P < 0.001)\) and a borderline significant effect for obesity \((P = 0.065)\) but no significant obesity effect or obesity \(×\) time interaction (ANOVA). *Significantly higher than ratings by normal-weight subjects, \(P < 0.05\) (t test).

![FIGURE 5](image_url)

**FIGURE 5.** Mean (±SEM) score of pleasantness of taste of the snacks on a 7-point hedonic scale \((1 = \text{very unpleasant}, 7 = \text{very pleasant})\) before (□) and after (●) eating 1 of the 4 products (chocolate candy bar, A; pears in light syrup, B; cheese crackers, C; fillet of chicken, D) to satiety for lunch \((n = 43)\). The decline in the pleasantness of taste of eaten products was significantly \((P < 0.001)\) greater than that of uneaten products. Initial liking scores (before lunch) differed significantly between the products \((P < 0.05)\). There were no significant differences between obese and normal-weight subjects.
an ANOVA, a significant main effect for time and a significant effect for the time × obesity interaction were found, but the main effect for obesity was not significant.

**DISCUSSION**

The results of this study do not confirm the hypothesis that there is a difference in sensory-specific satiety between obese and normal-weight subjects for products with high fat content. In fact, this study indicates that there is no difference in the degree of sensory-specific satiety for any of the foods tested between obese and normal-weight subjects. Both groups showed strong sensory-specific satiety for all tested products, but no differences were found between the groups in either liking, sensory-specific satiety, or the amount of food eaten to satiety. In the sandwich study, a stronger sensory-specific satiety was found for products high in fat (for both groups of subjects together), but this effect was not found in the snack study.

**Obese compared with normal-weight subjects**

Although there were no differences in sensory-specific satiety, there was a difference in residual hunger between the obese and normal-weight subjects. In both studies, obese subjects had larger appetite ratings ($P < 0.05$) after the ad libitum consumption of the sandwiches and snacks, whereas the before-lunch scores did not differ. This could indicate that obese subjects, although they ate on average the same amount of food as did the normal-weight subjects and liked the products before and after the ad libitum lunch as much as did the normal-weight subjects, were expressing a greater "wanting" for more food. We speculate that the differences between the obese and normal-weight subjects refer to differences in "wanting" and not to differences in

**TABLE 5**

Average intake of ad libitum lunch per group and per product by weight and energy content

<table>
<thead>
<tr>
<th>Intake</th>
<th>Chocolate candy bar</th>
<th>Pears in light syrup</th>
<th>Cheese crackers</th>
<th>Fillet of chicken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obese subjects, $n = 21$</td>
<td>130 ± 52</td>
<td>335 ± 158</td>
<td>70 ± 27</td>
<td>164 ± 97</td>
</tr>
<tr>
<td>(g)</td>
<td>2432</td>
<td>911</td>
<td>1658</td>
<td>1094</td>
</tr>
<tr>
<td>Normal-weight subjects, $n = 23$</td>
<td>122 ± 51</td>
<td>312 ± 119</td>
<td>71 ± 35</td>
<td>146 ± 49</td>
</tr>
<tr>
<td>(g)</td>
<td>2283</td>
<td>849</td>
<td>1681</td>
<td>974</td>
</tr>
<tr>
<td>Total subjects, $n = 44$</td>
<td>126 ± 51</td>
<td>324 ± 140</td>
<td>70 ± 31</td>
<td>155 ± 78</td>
</tr>
<tr>
<td>(g)</td>
<td>2357</td>
<td>881</td>
<td>1658</td>
<td>1034</td>
</tr>
</tbody>
</table>

*No significant differences were observed between obese and normal-weight subjects (t test).*
“liking” (31, 32). These results could also be explained on the basis of the higher energy needs of obese than of normal-weight subjects. An experiment like this does not distinguish between cause and effect. It does not answer the questions of whether greater appetite (after sensory-specific satiety) causes subjects to become overweight or whether the subjects’ overweight status itself results in a higher energy need and hence a greater appetite. These questions need further investigation.

Differences between products

Sandwiches high in fat produced stronger sensory-specific satiety than did sandwiches with low fat content, but that was not the case for the snacks. Hence, the apparent effect of fat in the sandwich study is probably due to factors other than fat content.

Products with similar taste declined in liking more than did products with similar fat content. This seems logical, because fat does not seem to be a primary taste sensation, ie, one for which a specific chemoreceptor exists. This means that sensory-specific satiety due to the presence of fat results, in fact, from the effect of fat on taste, flavor, and texture. Effects from varied fat content are therefore expected to be less specific than are the sensory effects of primary taste sensations for which specific chemoreceptors exist [ie, sweet, salty, sour, bitter, and umami (the fifth basic taste: the taste of glutamate)].

In the sandwich study, consumption of sandwiches with roast beef led to the lowest sensory-specific satiety. Because roast beef was the topping with the highest protein content (Table 3), and because it has been reported that consumption of high-protein foods leads to higher sensory-specific satiety than does that of low-protein foods (12), this was unexpected. An alternative explanation for the relatively low sensory-specific satiety for the roast beef sandwiches might be that the taste intensity of roast beef is relatively weak, especially because it was served with 2 slices of bread and without salt or pepper. A product with weak taste intensity is likely to produce weaker sensory-specific satiety than are products with stronger tastes, such as pâté and chocolate spread.

Intakes in the sandwich study were comparable to the average lunch intakes of Dutch women (33). In the snack study, intake of the different products varied largely in weight and energy content. Calorie intake was especially high for the chocolate candy bars and especially low for the pears in light syrup, probably because of their different energy densities, which are high and low, respectively. However, energy density does not seem to be the only factor affecting intake. Sensory aspects may also play a role, such as the easy-to-eat texture of the pears, which may encourage intake, or the very dry texture of the cheese crackers, which may inhibit intake. The design of this study fails to distinguish between fat content and the energy density of foods as factors that may determine intake, appetite, and decrease in liking, because the higher-fat items are also higher in energy density.

Subjects were instructed to eat until they reached satiety. To check whether they really did so, an unexpected second course was offered during the last session. In this second course, subjects were offered all 4 products after all the rating had been completed, and they were invited to eat as much as they wanted. Average intakes in this second course were low (22 g in the sandwich and 16 g in the snack study) and were especially low (<3 g) for the product that they had eaten for lunch. These intakes indicate that subjects ate to satiety and confirms that their satiety was sensory specific.

The appetite ratings also confirmed that satiety was sensory specific. There were significantly stronger declines in “appetite for something sweet” after a sweet meal and in “appetite for something savory” after a savory meal in both experiments.

Ratings of “pleasantness of taste” were used to measure sensory-specific satiety. It has been suggested that initial palatability is an important factor in determining sensory-specific satiety, but a significant effect has not been reported (3, 4). Although initial liking scores were found to differ somewhat between obese and normal-weight subjects in the study described here, these differences apparently had no effect on sensory-specific satiety observed in the obese and normal-weight subjects.

It is conceivable that the level of restraint in eating affects sensory-specific satiety, and we therefore investigated this possibility. A median split in the restrained-eating score resulted in 2 groups: one with subjects with a mean restrained-eating score >2.90 and one with subjects with a mean restrained-eating score <2.90. The first group had a mean (± SD) sensory-specific satiety score of 0.94 ± 0.83, and the second group had a score of 0.66 ± 1.04, but the mean sensory-specific satiety scores of the 2 groups did not differ significantly (t = 1.003, P = 0.322). Similarly, no significant correlation was found for the relation between sensory-specific satiety and restrained-eating score (Spearman’s ρ = 0.239, P = 0.118).

In this and other studies, sensory-specific satiety is measured through comparing subjective ratings before and after ad libitum consumption. Appetite was also assessed in this way. These scales have generally been shown to be reliable and valid, in the sense that they predict intake and choice (34). However, these ratings reflect conscious, rationalized liking and wanting. Berridge (32) suggested, “Subjective reports may contain false assessments of the underlying processes, or even fail to register important reward processes. The core processes of liking and

![Figure 8](image-url)
wanting that constitute reward are distinct from the subjective report or conscious awareness of those processes.”

The observations of Berridge (32) suggest that we must find better ways to measure liking and wanting if we are to study possible differences between obese and normal-weight humans. One way might be with the help of neuroimaging techniques to study sensory-specific satiety, as was done by O’Doherty and Rolls (35). Another way might be the design of behavioral experiments that measure “liking” and “wanting” in a more reliable (indirect) way than do subjective ratings. Epstein et al have conducted several such studies (36).

In conclusion, the results of this study show that obese and normal-weight subjects do not differ in sensitivity to sensory-specific satiety and suggest that taste is more important than is fat content in causing sensory-specific satiety. After eating a single product to satiety, obese subjects still had more appetite than did normal-weight subjects.

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