Satiation Due to Equally Palatable Sweet and Savory Meals Does Not Differ in Normal Weight Young Adults1–3

Sanne Griffioen-Roose,4,∗ Monica Mars,4 Graham Finlayson,5 John E. Blundell,5 and Cees de Graaf4

Abstract

Sensory properties are greatly involved in the process of satiation. Regarding the nature of sensory signals, an important distinction can be made between sweet and savory taste. It is unclear, however, whether sweet and savory differ in their influence on satiation. Our objective was to investigate the difference between a sweet and savory taste on satiation, independent of palatability, texture, energy density, and macronutrient composition. A crossover design was used, consisting of 3 test conditions in which 2 tastes (sweet and savory) were compared. Sixty-four healthy, nonsmoking, unrestrained participants (18 males and 46 females), with a mean age of 22.3 ± 2.4 y and a mean BMI of 21.6 ± 1.7 kg/m², enrolled. Rice was used as a test meal served in either a sweet or savory version. The meals were similar in palatability, texture, energy density, and macronutrient composition. Ad libitum intake, eating rate, and changes in pleasantness and appetite during the meals were measured. Ad libitum intake did not differ between the 2 meals; participants ate a mean of 144 g of the sweet meal and 333 g of the savory meal. Eating rate (sweet, 38 ± 14 g/min; savory, 37 ± 14 g/min) and changes in pleasantness and appetite during the meals were similar. Homogeneous meals with a sweet or savory taste, similar in palatability, texture, energy density, and macronutrient composition, do not differ in their influence on satiation in normal weight young adults. J. Nutr. doi: 10.3945/jn.109.110924.

Introduction

Satiation is defined as the process that develops during eating and brings an eating episode to an end (1). In terms of preventing overconsumption, it is important to identify properties of foods that influence this process. Regarding energy balance, no strong relationship has been found between eating frequency and body weight (2,3). Because weight gain is characterized by excess energy intake (4–8), meal size might be an important factor contributing to obesity.

Numerous studies have shown that palatability plays a key role in satiation [for review, see (9)]. Enhancing palatability results in an increased intake, observed both inside and outside the laboratory (10–12). Other properties of food shown to influence satiation are weight/volume (13–15), texture (16), and macronutrient composition (17,18). Energy density might play a role as well but appears to involve learning processes (19,20).

Most of above-mentioned factors are thought to play a role in satiation through the sensory properties of the food (1,9,21). When a food is eaten to satiety, the pleasantness of that food is decreased in comparison to foods that have not been eaten (22). This is called sensory-specific satiety (SSS). SSS can be detected within 2 min after consumption has started, before digestion and absorption can occur, and therefore specific for the sensory properties of the eaten food. Because SSS can be an important factor for meal termination (1,23), we might better speak of sensory-specific satiation. This refers to the decline in reward (24) during consumption of a food, i.e. due to repeated exposure to a particular sensory signal.

Regarding sensory signals, an important distinction can be made between sweet and savory taste, which includes almost 90% of the food we eat (25). It is unclear, however, whether sweet and savory differ in their influence on satiation.

Our objective was to investigate the difference between a sweet and savory taste on satiation, independent of palatability, texture, energy density, and macronutrient composition. We assessed this by comparing homogeneous rice meals with a sweet and savory taste. It is our hypothesis that sweet taste suppresses hunger less and stimulates appetite more compared with a savory taste, resulting in a lower intake of the savory meal. A second part of our study focused on the effect of taste on satiety processes; however, these results are outside the scope of this paper.

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2 Author disclosures: S. Griffioen-Roose, M. Mars, G. Finlayson, J. E. Blundell, C. de Graaf, no conflicts of interest.
3 Supplemental Figures 1 and 2 are available with the online posting of this paper at jn.nutrition.org.
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Materials and Methods

Participants. Healthy, normal weight participants, aged 18–35 y, were recruited from Wageningen and the surroundings. Exclusion criteria were restrained eating [Dutch eating behavior questionnaire: men score \( >2.25 \); women score \( >2.80 \) (26)], lack of appetite, an energy-restricted diet during the last 2 mo, change in body weight \( >5 \) kg during the last 2 mo, stomach or bowel diseases, diabetes, thyroid disease or any other endocrine disorder, having difficulties with swallowing/eating, hyper-sensitivity for food products under study, smoking, being a vegetarian, and for women being pregnant or lactating. Body weight and height were measured. In total, 64 participants (18 males and 46 females) aged 22.3 ± 2.4 y, with a mean BMI of 21.6 ± 1.7 kg/m\(^2\) enrolled in the study. All participants completed the study and received financial compensation.

Participants were unaware to the exact aim of the study and were informed we were interested in comparing several methods of assessing palatability of rice products. The study was approved by the Medical Ethical Committee of Wageningen University and all participants signed an informed consent.

Design. We used a randomized crossover design consisting of 3 test conditions in which 2 tastes (sweet and savory) were compared, resulting in 6 experimental conditions (Fig. 1). The wash-out period between the experimental conditions was at least 3 d. Preceding the experiment there was one practice day to accommodate participants to the test conditions.

Test food. Two versions of a rice meal were used as test products: a sweet and a savory version. Similarity on palatability and texture was established with a pilot study (Supplemental Fig. 1). By comparing the sweet meal with 5 different sucrose concentrations (0, 0.125, 0.25, 0.5, and 1 mol/L) and the savory meal with 5 different NaCl concentrations (0, 0.125, 0.25, 0.5, and 1 mol/L) perceived intensity of both meals could be expressed in physical units (27). It was shown that the sweet meal had a perceived intensity that was comparable to 0.38 mol/L sucrose in water and perceived intensity of the savory meal was comparable to 0.22 mol/L NaCl in water. Prior to the study, energy and macronutrient contents were calculated using the Dutch nutrient database (28). Afterwards, macronutrient content was determined by chemical analysis of samples taken from a homogenous mixture of samples that were collected every testing day (Table 1).

The core component of both meals was risotto rice (Lassie) (78.0%). The sweet version was made with semiskimmed milk (17.0%), butter (2.2%), cinnamon (0.08%), vanilla sugar (0.5%), and aspartame (3.0%). The savory version was made with semiskimmed milk (12.0%), crème fraîche (8.0%), bouillon (0.3%), garlic powder (0.02%), and NaCl (0.8%). A standardized protocol was used to make fresh meals every morning prior to the test and they were kept warm at a mean temperature of 75°C (range 65°C–85°C). The meals were served in large bowls containing 800 g and were consumed with a tablespoon.

Procedure and data collection. On test days, participants were instructed to eat a normal, standardized breakfast and standardize their morning physical activities. They were not allowed to eat or drink anything except for non-energy-containing beverages 3 h before the start of a test session and were not to consume anything in the previous hour before the start. Furthermore, they were instructed not to eat anything until 1 h after the test to make sure they consumed the test product until they were satiated. Tests were scheduled during lunchtime and performed in isolated tasting booths throughout the experiment. There were 3 time shifts: 1130–1215, 1230–1315 and 1330–1415. All experimental measurement of 1 participant took place in the same time shift.

When participants arrived at the laboratory they were seated and given specific instructions depending on test condition (described below) shown on a computer screen. In all test conditions, participants were offered an ad libitum meal with instructions “to eat as much as they liked, until comfortably satiated.” Food intake was monitored using a hidden scale (model KERN 440, ATP-Messtechnik) that was connected to a computer. The computer was programmed (VISUAL BASIC) to record weight with a 2-s interval throughout the meal with a precision of 0.1 g. When weight of the meal fell below 100 g, a researcher was alerted by the computer and the bowl was replaced with a new one (during the experiments, this happened in total 8 times for 2 male participants; 4 times each). To reduce errors in weighing, participants were given instructions to avoid contact with the bowl, to only take food onto their spoon until ready to ingest it, and to leave the spoon next to the food bowl when completing ratings or finished eating. Ad libitum intake and total eating time were recorded for all experimental conditions. The used appetite questionnaire consisted of 5 dimensions: hunger, fullness, prospective consumption, desire to eat something sweet, and desire to eat something savory. For pleasantness ratings a distinction was made between ‘pleasantsens of the taste’ and ‘desire to eat the food.’ All ratings were performed on a computer on a 100-u VAS, anchored with ‘not at all’ to ‘extremely.’

During test sessions a cup of 200 mL tap water was available. If needed, the experimenter refilled the cup. Ad libitum intake of water was measured afterwards by weighing the residues in the glasses. Intake of water did not significantly differ between the 2 meals in any of the test conditions (test condition 1: sweet meal, 149 ± 81 g vs. savory meal, 159 ± 73 g; test condition 2: sweet meal, 295 ± 123 g vs. savory meal, 295 ± 119 g; test condition 3: sweet meal, 164 ± 95 g vs. savory meal, 168 ± 98 g). In test condition 2, however, overall intake of water was higher due to obliged intake during sample rating (P < 0.001).

Procedures of the different test conditions were as follows. In test condition 1, once seated, participants received a bowl of rice. After finishing eating, they left. In test condition 2, participants first filled out the appetite questionnaire. Then they received a plate containing 6 samples of rice (each weighing ~5 g), varying in taste and intensity. Participants were instructed to neutralize their mouth with a sip of water after tasting and rating the different samples. Afterwards, participants received a bowl of rice. They had to taste a bite and rate the pleasantness, after which they could start eating. When 50 g (1 bout) was consumed, the computer gave a buzz, accompanied with on-screen instructions to stop eating and perform pleasantness and appetite rating.

Test condition 1

Test condition 2

Test condition 3

Sweet meal ratings: every 50g (bout)

Savory meal ratings: every 50g (bout)

Appetite and Pleasantness ratings (sample ratings)

Appetite ratings (FPQ)

FIGURE 1 Crossover study design.
TABLE 1  Energy content and values of the chemical analysis of macronutrient composition per 100-g test meal1

<table>
<thead>
<tr>
<th></th>
<th>Sweet meal</th>
<th>Savory meal</th>
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<tbody>
<tr>
<td>Energy content, kcal/kJ</td>
<td>112/470</td>
<td>98/411</td>
</tr>
<tr>
<td>Protein, g</td>
<td>1.8 (6)</td>
<td>2.0 (8)</td>
</tr>
<tr>
<td>Carbohydrate, g</td>
<td>20.4 (73)</td>
<td>17.4 (71)</td>
</tr>
<tr>
<td>Fat, g</td>
<td>2.6 (21)</td>
<td>2.3 (21)</td>
</tr>
<tr>
<td>Fiber, g</td>
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</table>

1 Values determined by chemical analysis of samples taken from homogenous mixture of samples collected every testing day and % of the total energy content of the test product (in parentheses). Nitrogen was determined by the Kjeldahl method [149 method 920.87], and the amount of protein was calculated using a conversion factor of 6.25; fat by the acid hydrolysis method [149 method 14.019]; available carbohydrate was calculated by subtracting moisture, ash, protein, dietary fiber and fat from total weight. Energy content was calculated from the macronutrient composition by using the following energy conversion factors: protein, 16.7 kJ/g; fat, 37.7 kJ/g; carbohydrate, 16.7 kJ/g (% of the total energy content of the test product).

ratings, after which eating was continued until the next bout was consumed. This cycle continued until participants indicated they were satiated. They were then asked to repeat pleasantness and appetite ratings. Lastly, participants received a new plate of six rice samples and rated them. In test condition 3, participants rated their appetite similarly as in test condition 2. Afterwards, explicit and implicit aspects of food choice were assessed by means of a computerized food preference questionnaire (FPQ). Next, participants received a bowl of rice. When participants indicated they were satiated, they had to rate their appetite and the FPQ was rerun.

Please note that results of “desire to eat something sweet/savory” ratings and rice sample ratings of test condition 2 and the FPQ of test condition 3 are not discussed in this current paper but are only mentioned to give an overview of the experimental setting.

Statistical analyses. Data presented are means ± SD. For test condition, ad libitum intakes (g) were compared between the 2 meals using a paired t test. Differences in overall intake between the 3 test conditions were compared with a 1-way ANOVA (PROC GLM) with participant and test condition as independent variables.

For test condition 1, eating rate (total intake divided by total consumption time) was compared between the 2 meals with a paired t test. Interaction between time and intake was compared between the 2 meals by means of a mixed-model ANOVA (PROC mixed with fixed factors time, product, and time × product and random factor participants).

For test conditions 2 and 3, initial ratings were compared and analyzed by means of a paired t test. Change scores were calculated by subtracting ratings before the meal from ratings after the meal. Differences in change scores between the sweet and savory meal were analyzed using a paired t test. Mean ratings of pleasantness and appetite during the meals, measured in test condition 2, were calculated per bout and compared between tastes by means of a t test. Initial pleasantness and appetite ratings were tested for correlation to intake (Pearson correlation coefficient) and 95% CI were calculated.

To take into account individual preferences for sweet or savory foods, a computerized food preference questionnaire (FPQ) was rerun. Afterwards, explicit and implicit aspects of food choice were assessed by means of a computerized food preference questionnaire (FPQ). Next, participants received a bowl of rice. When participants indicated they were satiated, they had to rate their appetite and the FPQ was rerun.

Please note that results of “desire to eat something sweet/savory” ratings and rice sample ratings of test condition 2 and the FPQ of test condition 3 are not discussed in this current paper but are only mentioned to give an overview of the experimental setting.

Table 2

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Results

Ad libitum intake. Ad libitum intakes of the sweet and savory meals per test condition did not differ (Fig. 2). Overall intake in test condition 2 was lower compared with intakes in test conditions 1 and 3 (P < 0.001).

In test condition 1, total eating time comprised 8.7 ± 3.4 min for the sweet and 9.2 ± 4.1 min for the savory meal and overall eating rate was similar (38 ± 14 g/min for the sweet meal and 37 ± 14 g/min for the savory meal). There was a main effect of time for both meals (P < 0.0001). However, there was no effect of meal or the time × meal interaction.

In the other 2 test conditions, total eating time of the sweet and savory meals did not significantly differ. In test condition 2, total eating time comprised 8.9 ± 4.2 min for the sweet and 9.6 ± 4.5 min for the savory meal. In test condition 3, total eating time comprised 8.2 ± 3.2 min for the sweet and 8.7 ± 4.5 min for the savory meal.

Of the 64 participants, 16 were categorized as high-sweet likers (pleasantness sweet meal, 75 ± 10 vs. savory meal, 37 ± 20), 14 were categorized as high-savory likers (pleasantness sweet meal, 29 ± 17 vs. savory meal, 74 ± 12), and 34 were indifferent (pleasantness sweet meal, 68 ± 15 vs. savory meal, 68 ± 14).

The indifferent group ate similar amounts of both meals: 319 ± 168 g of the sweet meal and 328 ± 173 g of the savory meal. High-sweet likers ate more of the sweet meal (295 ± 168 g) than of the savory meal (203 ± 151 g) (P < 0.01). High-savory likers ate more of the savory meal (216 ± 127 g) than of the sweet meal (155 ± 104 g) (P < 0.001).

Pleasantness and appetite ratings. Initial ratings were similar before the 2 experimental conditions (Table 2). Changes in rating were significant but did not differ between the 2 meals.

The number of bouts consumed varied among participants (5.1 ± 3.2). Pleasantness and appetite ratings did not differ between the 2 meals for any of the bouts (Fig. 3; Supplemental Fig. 2).

Correlations. Initial pleasantness ratings, measured in test condition 2, were correlated with intake (Table 3). Only initial prospective consumption, measured in test condition 2, was correlated to intake of the savory meal. In test condition 3, both initial hunger and initial prospective consumption were correlated with intake of the savory meal. None of the appetite ratings were correlated with intake of the sweet meal.

Discussion

Our objective was to investigate the difference between a sweet and savory taste on satiation, independent of palatability,
texture, energy density, and macronutrient composition. Intake did not differ between the 2 meals. Progress of the meals and eating rates were similar. Both the sweet and savory meals suppressed hunger and prospective consumption and increased fullness equally during the eating episode.

These findings were not consistent with our hypothesis. The circadian rhythm of appetite for something sweet and appetite for something savory show different patterns during the day; appetite for something savory is more meal/hunger related, whereas appetite for something sweet is more stable (29,30). In addition, it has been observed that appetite for something sweet is less suppressed by a meal than appetite for something savory (31,32). And studies have shown that sweetness might have a stimulatory effect on appetite and is therefore less satiating than savoriness (9,31–33).

Several studies showed that the intake of sweet products was higher than of savory products (32,34,35). The products used in these experiments, however, differed greatly, not only in energy density but also in sensory properties. Components other than these experiments, however, differed greatly, not only in energy density but also in sensory properties. Components other than these mechanisms were not involved. In all test conditions, however, eating time was <10 min. In addition, by controlling the composition of both meals, we do not think postingestive satiety mechanisms influenced our outcome.

Results of all 3 test conditions showed that satiation did not differ between the sweet and savory meal. In test condition 2, however, an overall lower intake was observed. This could have been due to the exposure of rice samples and water before the meal; the rice samples in total were ~30 g and participants knew they would receive them again after the meal. Interruptions during the meals could also have caused lower intake. It led to a

It might be that the stimulatory effect of sweetness on appetite is only valid for a certain population. Laeng et al. (36) reported that both gender and degree of individual “sweetness liking” influenced the experience of sweet tastes. Appleton et al. (31,37) showed that low consumers of artificially sweetened beverages demonstrated an increase in appetite in response to sweet taste, whereas high consumers did not. Our high-sweet likers ate more of the sweet meal than of the savory meal. Whether this was due, however, to a stimulatory effect of sweetness or to liking of the product (high-savory likers ate more of the savory meal) is unclear. Due to the small number of participants in these groups, no elaborate analysis could be performed.

We focused primarily on sensory-specific satiation. Alongside sensory properties, however, environmental/contextual factors and cognitive factors appear to play a role (1). Although environmental factors were controlled for (all sessions were conducted under similar circumstances), cognitive factors might have contributed to our outcome. Through consumption of foods during our lifetime, we learn to estimate their satiating effects. This plays an important and independent role in decisions about portion size (38,39). Although we did not assess beliefs about our meals, the appearance, texture, and core product (rice) were very similar, which might explain equal intake of both meals.

Another factor that might have contributed to equal intake is visual cues, which have been shown to greatly influence portion size (15). Although we tried to avoid this by serving the meals in large quantities, participants might still have been able to determine their intake by using visual cues, also because the appearance of both meals was so similar.

In our study, we let participants ingest the meals. Therefore, we cannot with certainty claim that postingestive satiety mechanisms were not involved. In all test conditions, however, eating time was <10 min. In addition, by controlling the composition of both meals, we do not think postingestive satiety mechanisms influenced our outcome.

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TABLE 3  Pearson correlations between initial pleasantness and appetite ratings with ad libitum intake in normal weight young adults

<table>
<thead>
<tr>
<th>Intake sweet meal</th>
<th>Intake savory meal</th>
</tr>
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<tbody>
<tr>
<td>Test condition 2</td>
<td></td>
</tr>
<tr>
<td>Pleaseness ratings</td>
<td></td>
</tr>
<tr>
<td>0.50*** (0.29–0.66)</td>
<td>0.34* (0.10–0.54)</td>
</tr>
<tr>
<td>Desire to eat the food</td>
<td>0.52*** (0.31–0.68)</td>
</tr>
<tr>
<td>Appetite ratings</td>
<td></td>
</tr>
<tr>
<td>Hunger</td>
<td></td>
</tr>
<tr>
<td>0.09 (−0.16–0.32)</td>
<td>0.19 (−0.06–0.41)</td>
</tr>
<tr>
<td>Fullness</td>
<td></td>
</tr>
<tr>
<td>−0.04 (−0.28–0.21)</td>
<td>−0.14 (−0.37–0.11)</td>
</tr>
<tr>
<td>Prospective consumption</td>
<td>0.17 (−0.08–0.40)</td>
</tr>
<tr>
<td>Test condition 3</td>
<td></td>
</tr>
<tr>
<td>Appetite ratings</td>
<td></td>
</tr>
<tr>
<td>Hunger</td>
<td></td>
</tr>
<tr>
<td>−0.00 (−0.25–0.25)</td>
<td>0.38* (0.14–0.57)</td>
</tr>
<tr>
<td>Fullness</td>
<td></td>
</tr>
<tr>
<td>−0.06 (−0.30–0.19)</td>
<td>−0.14 (−0.37–0.11)</td>
</tr>
<tr>
<td>Prospective consumption</td>
<td>0.13 (−0.12–0.38)</td>
</tr>
</tbody>
</table>

1 Asterisks indicate significant correlations: *P < 0.01; **P < 0.001; ***P < 0.0001; n = 64.

**TABLE 3** Pearson correlations between initial pleasantness and appetite ratings with ad libitum intake in normal weight young adults

slower eating rate, which has been linked to smaller intake (40). And when pauses are introduced, participants are cognitively more aware that they can stop eating (41), although Yeomans et al. (42) reported that interruptions increased intake. Due to our design, we cannot distinguish these processes and their effects, but we do know that they influenced the 2 meals equally.

It can be argued whether our products were similar in energy density. The compositions of both meals were calculated using the Dutch nutrient database (28). Chemical analysis afterwards showed that the similarity of energy density was less than had been established. Numerous studies have shown, however, that within a meal, participants do not compensate for energy intake (19,43). And if energy density does play a role, it probably involves learning processes (20). When examining the order effect of both meals (each was given 3 times to participants), no effect of time was evident (data not shown). We are therefore confident that the difference in energy density did not affect our outcome.

The changes in pleasantness ratings for both meals were significantly decreased after finishing the meal, which is an indicator for SSS (Table 2). When inspecting the ratings in the first bouts, however, this decrease is not visible (Fig. 3B,C). This maybe due to the fact that intake of the meals was ad libitum and therefore participants were progressively eliminated from the analysis.

When comparing the correlation of the sweet and savory meals, initial pleasantness ratings were strongly correlated with intake. Appetite ratings for hunger and prospective consumption were correlated to intake of the savory meal and not to the sweet meal (Table 3). This seems to be consistent with observations that appetite for something savory is more related to meal time/hunger feelings than appetite for something sweet (29,30). Because the correlation of intake and hunger was not replicated in test condition 2, however, more research is needed to clarify this finding.

Our results are in concordance with a study performed by Rolls et al. (44). They investigated the effect of serving a sweet or savory food, equal in energy density and palatability, as either a first or last course in a 3-course meal. Intake of the sweet and savory products before the main course was similar. After the savory main course, however, intake of the sweet product appeared to be higher than of the savory product (not main outcome). This is an example of many studies showing that sweet and savory taste do differ on several aspects. SSS research has shown that eating either taste (sweet or savory) to satiety invariably leads to a decrease in the pleasantness of foods with similar taste (31,32,45,46), leading to adjusted food choice and intake (44,47,48).

To quantify the role of sensory properties on food intake, research with single foods is the most sensitive and provides clear results. In everyday life, however, we ingest varied meals, which have a more complex taste, in a less controlled environment. It is therefore difficult to extrapolate these findings to everyday life. There are still many eating occasions, however, in which people eat homogeneous or single foods.

In conclusion, we have shown that homogeneous meals with a sweet or savory taste, similar in palatability, texture, energy density, and macronutrient composition, do not differ in their influence on satiation in normal weight young adults. We therefore postulate that, when considering that the sweet-savory domain is an important dimension from taste perspective, taste seems not to have a large influence on satiation in equal palatable foods. However, more research, including testing other foods, is needed to strengthen this claim.

**Acknowledgments**

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