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Research report

Taste of a 24-h diet and its effect on subsequent food preferences and satiety ☆

Sanne Griffioen-Roose [a,*], Pleunie S. Hogenkamp [a], Monica Mars [a], Graham Finlayson [b], Cees de Graaf [a]

[a] Division of Human Nutrition, Wageningen University, P.O. Box 8129, 6700 EV Wageningen, The Netherlands
[b] Biopsychology Group, Institute of Psychological Sciences, University of Leeds, Leeds, UK

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ABSTRACT

The objective of this study was to investigate the effect of taste of a 24-h diet on subsequent food preferences (food choice and intake of specific food categories) and satiety. We used a crossover design, consisting of a 24-h fully controlled dietary intervention, during which 39 healthy subjects consumed diets that were predominantly sweet tasting, savory tasting, or a mixture. The diets were similar in energy content, macronutrient composition, and number of different products used. Following the intervention an *ad libitum* lunch buffet was offered the next day, consisting of food items differing in taste (sweet/savory) and protein content (low/high) and intake was measured. The results showed that the taste of the diet significantly altered preference for food according to their taste properties ($p < 0.0001$); after the savory diet, intake of sweet foods was higher than of savory foods. After the sweet diet, savory foods tended to be preferred ($p = 0.07$). No interaction was seen between the taste of the diet and food preference according to their protein content ($p = 0.67$). No differences in total energy intake (kJ) at the *ad libitum* lunch buffet were observed ($p = 0.58$). It appears that in healthy subjects, taste of a 24-h diet largely affects subsequent food preferences in terms of sensory appetite, whereby savory taste exerts the strongest modulating effect. Taste of a 24-h diet has no effect on macronutrient appetite.

Introduction

Sensory attributes of food are the primary drivers of food selection and food intake (Blundell, Rogers, & Hill, 1987; Sørensen, Møller, Flint, Martens, & Raben, 2003; Swithers & Hall, 1994). It has been established that the process of satiation is to a large extent mediated by sensory processes, generated from the sensory qualities of food. When a food is eaten to satiety, the pleasantness of the sensory properties of that food decreases more than of foods that have not been eaten. This is termed sensory specific satiety (SSS) and was first demonstrated in humans by Rolls, Rolls, Rowe, and Sweeney (1981). Decreasing pleasure from exposure to the sensory qualities is a key factor believed to contribute to the termination of a meal (Sørensen et al., 2003; Swithers & Hall, 1994).

SSS has been demonstrated for several attributes of food, including, taste, smell, texture, and appearance (e.g. Guinard & Brun, 1998; Rolls, Rowe, & Rolls, 1982a, 1982b; Romer et al., 2006; Sørensen et al., 2003; Vickers, Holton, & Wang, 1998; Weijzen, Liem, Zandstra, & de Graaf, 2008). Moreover, not only eaten foods, but also foods that share sensory characteristics of the eaten foods decline in pleasantness relative to food that do not share these properties; a so-called transfer effect (Griffioen-Roose, Finlayson, Mars, Blundell, & de Graaf, 2010; Rolls, Vanduijvenvoorde, & Rolls, 1984). The role of sensory signals in more long-term food preferences and intake needs further clarification (Cabanac & Rabe, 1976; Köster & Mojet, 2007; Weenen, Stafleu, & de Graaf, 2005).

It is conceived that through repeated consumption of food during our lifetime we learn to associate the sensory attributes of food with their physiological effect and consequently learn to estimate their metabolic effects (Booth, 1972, 1985). This associative learning influences selection of food and food intake and has been suggested to play a central role in the development of specific sensory (i.e. appetite for foods with a certain taste, for example appetite for something savory) and macronutrient (i.e. appetite for foods high in a certain macronutrient, for example protein) appetites (Baker, Booth, Duggan, & Gibson, 1987; Gibson, Wainwright, & Booth, 1995). An important distinction regarding sensory signals can be made between sweet and savory[1] taste, which includes almost 90% of the food we eat (Mattes, 1985). Over the course of a day, profiles of appetite for something savory and appetite for something sweet show different patterns; it appears that appetite for some-

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* Corresponding author.
E-mail address: sanne.griffioen-roose@wur.nl (S. Griffioen-Roose).

[1] Savory taste refers to non-sweet, salty taste, closely linked to the 'umami-taste', and is also described as 'brothy' or 'meaty' (Yamaguchi & Ninomiya, 2000).

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thing savory oscillates more in line with the pattern of meals, i.e. more related to feelings of hunger, whereas appetite for something sweet is more stable during the day (de Graaf, 1993).

Interestingly, within our food range, savory-tasting foods contain in general higher levels of protein, while sweet-tasting foods contain more carbohydrates (Blundell, Green, & Burley, 1994; Luscombe-Marsh, Smeets, & Westerterp-Plantenga, 2008; Viskaal-van Dongen, van den Berg, Vink, Kok, & de Graaf, 2011). As in humans, the range of protein intake has remained relatively constant over time and across the population, it has been argued that protein intake is tightly regulated (Metcalf et al., 2008; Simpson, Batley, & Raubenheimer, 2003; Simpson & Raubenheimer, 2005). Several studies have shown a positive association between feelings of hunger and appetite for high-protein savory tasting foods (Barkeling, Rossner, & Bjorvell, 1990; Hill & Blundell, 1986; Vazquez, Pearson, & Beauchamp, 1982). The role of sweet and savory sensory signals in food intake regulation beyond a single eating occasion needs further clarification. Therefore the objective of this study was to investigate the effect of taste of a 24-h diet on subsequent food preferences (food choice and intake of specific food categories) and satiety.

The approach consisted of measuring the effect of three different 24-h diets that were either predominantly sweet tasting, predominantly savory tasting or a mixture of sweet and savory tasting. Afterwards food intake was measured during an *ad libitum* lunch buffet where a large array of food items was available differing in taste (sweet/savory) and protein (low/high). We hypothesized that through the transfer effect of sensory specific satiety, the taste of the diet would direct food preferences to foods with a dissimilar taste. In addition, it was hypothesized that this modulation would occur in relation to the protein content of the offered food products, i.e. that a savory diet would modulate food preferences to sweet low protein foods.

Subjects and methods

Subjects

Thirty-nine subjects (11 males, 28 females) aged 21 ± 2 years, with a mean BMI of 21.3 ± 1.7 kg/m^2 completed the study. Healthy, normal weight subjects (BMI between 18.5 and 25), aged 18–35 years were recruited. Exclusion criteria were the following: restrained eating (Dutch Eating Behavior Questionnaire (DEBQ), men: score > 2.25, women: score > 2.8) (Van Strien, 2005), lack of appetite, an energy restricted diet during the last two months, change in body weight >5 kg during the last two months, stomach or bowel diseases, diabetes, thyroid disease or any other endocrine disorder, use of daily medication other than birth control pills, having difficulties with swallowing/eating, hypersensitivity for the foods used in the study, smoking, being a vegetarian, and for women, being pregnant or lactating.

Potential participants filled out an inclusion questionnaire including a medical history questionnaire. In addition, the general liking of the products offered during the *ad libitum* lunch was assessed with a food questionnaire containing pictures of these foods and for inclusion, at least one product of each category (see '*ad libitum* lunch buffet') should be scored average or higher. Then they attended a screening/training session, which included measurement of weight and height to check whether BMI was within the inclusion criteria. In addition, the test procedures were explained. Of the 42 subjects which were invited for screening, three were excluded because their BMIs were <18.5. Subjects were unaware to the exact outcome measurements of the study (food intake) and were informed we were interested in the effect of taste on food habits and specifically how to measure this. The present study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures were approved by the Medical Ethical Committee of Wageningen University. This trial has been registered with the Dutch Trial Register (NTR) (registration no. NTR 2875). Written informed consent was obtained from all subjects.

Design

The crossover study consisted of a 24-h fully controlled dietary intervention, where subjects consumed three diets that were either predominantly sweet tasting, predominantly savory tasting or a mixture of sweet and savory tasting (Fig. 1). The diets were similar in energy content, macronutrient composition, and number of different products used. The three 24-h diets were scheduled in three subsequent weeks, always starting with a lunch on Tuesday. The order of the diets was randomized for each subject according a generalized Latin square design. Following the intervention, an *ad libitum* lunch buffet was offered on Wednesday, consisting of food items differing in taste (sweet/savory) and protein level (low/high) and food intake was measured. In addition, during the intervention, feelings of appetite were assessed every waking hour and the Leeds Food Preference Questionnaire (LFPQ) was completed before the *ad libitum* lunch (Finlayson, King, & Blundell, 2007; Griffioen-Roose et al., 2010).

Test foods

Diets

Each subject's total energy requirement was estimated by means of the Schofield I equation (WHO, 1985), taking into account age, weight, sex, and a physical activity level of 1.6. Based on this calculation, subjects were assigned to either an 8 MJ diet (n = 15), an 11 MJ diet (n = 21), or a 13 MJ diet (n = 3). The composition of the three diets is shown in Table 1a and comprised of products that had sweet or savory versions (Table 1b). Foods were provided during a fixed lunch and in a fixed home package. The fixed lunch comprised of a rice meal with a tomato salad and a shake. The fixed home package contained two bread meals and afternoon, evening, and morning snacks. Macronutrient composition of all diets was matched for each separate eating occasion.

The mixed diet comprised of products that were all used in the sweet and savory diets and products with a bland taste. However, to avoid this diet containing a larger number of different products, two mixed diets were compiled. All the products of the sweet and savory diets were divided over these two diets (Table 1b). In terms of palatability and composition, mixed diet #1 was slightly more similar to the sweet diet, and mixed diet #2 slightly more similar to the savory diet (Table 1a). The subjects were randomly divided over the two mixed diets (Mixed diet #1, n = 20; Mixed diet #2, n = 19).

Ad libitum lunch buffet

The buffet consisted of sixteen food products that were selected on the basis of their taste (sweet/savory) and protein content (low/high). The resulting four food categories [low-protein sweet (LPSW), high-protein sweet (HPSW), low-protein savory (LPSA), and high-protein savoury (HPSA)] were matched on energy density, fat content, and type of food (each category contained one meal item, one salad, one sandwich, and one semi-solid product). Energy content and macronutrient composition of the selected products are shown in Table 2. The food products were offered in large quantities, and if they consisted of single pieces these were around 40 g (pancakes 34 g, apple turnovers 43 g, small pizzas 30 g, rösti rounds 43 g). The buns were 22 g with 22 g of topping.