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Effects of aroma–texture congruency within dairy custard on satiation and food intake

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ABSTRACT

Food intake regulation comprises numerous components from peripheral and central pathways, including sensory and cognitive elements. This study investigated if congruency in different aroma–texture combinations within a dairy product influences satiation and food consumption in humans. Among seven different aromas, vanilla was rated as congruent and lemon as incongruent aroma in the context of creamy texture, while both aromas were highly liked and familiar. Creamy custard, either vanilla- or lemon-aromatised, was given to 32 subjects in a preload – *ad libitum* regimen. Satiation was measured on visual analogue scales and by salivary α-amylase concentration. Finally, the amount of *ad libitum* intake was determined. No effects of congruency were found on *ad libitum* consumption and perceived satiation. Subjects felt more satiated when preload and *ad libitum* intakes shared the identical aroma compared to varied aromas. This was not supported by increased salivary α-amylase levels, although those increased overall with intake. In conclusion, there was no relation between congruency in aroma and texture in dairy custard and food intake, but aroma perception possibly modulates perceived satiation.

1. Introduction

Food intake regulation in humans involves a variety of homeostatic, behavioural, sensory and hedonic components controlled by systems conveying both peripheral and central pathways. Mostly peripheral signals provide information about the body's nutritional state, which can serve as physiological biomarkers of energy balance, and the central nervous system integrates episodic hunger and satiety signalling towards a functional output that controls metabolism with accompanying behaviour (Gale, Castracane, & Mantzoros, 2004; Schwartz, Woods, Porte, Seeley, & Baskin, 2000). Recently, we demonstrated a strong association between perceived satiety and the autonomic nervous system status as well as saliva composition, including salivary α-amylase levels, in humans (Harthoorn et al., 2007; Harthoorn & Dransfield, 2008). While signalling between periphery and brain is crucial in coordinating integrative processes for metabolism, it can also be anticipatory as it can occur even before food is ingested (Bellisle, Louis-Sylvestre, Demozay, Blazy, & Le Magnen, 1985; Mattes, 1997).

With regard to the effects of food intake on satiety, two distinct phases have been considered within the postulated "satiety cascade" (Blundell, Lawton, Cotton, & Macdiarmid, 1996). First, "satiation" is defined as a short-term process which develops during eating and brings an eating episode to an end. Second, "satiety" is termed as a longer-term state of inhibition over further eating. This satiety cascade takes into account properties of food, physiological processing of nutrients and factors that contribute to overall control of food intake, and it also conceptualises differences between immediate post-ingestive effects of food and effects produced later. In most cases active ingredients incorporated into food products are aimed to have their effects in the post-ingestive and post-absorptive phases. However, the use of sensory triggers and in particular aromas, which take part in the early phases of the satiety cascade and contribute to the process of meal termination, has also been reported (Hirsch & Gomez, 1995; Mayer, Davidson, & Hensley, 1999; Ruijschop, Boelrijk, De Ru, De Graaf, & Westerterp-Plantenga, 2008).

As food is eaten, continued exposure to its appearance, taste, mouth feel and smell, may result in reduced pleasantness and desire to eat that specific food. This phenomenon is called

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"sensory-specific satiety" because it occurs in the relatively short-term before a meal is digested and absorbed (Hetherington, 1996; Rolls, Rowe, & Rolls, 1982; Sørensen, Møller, Flint, Martens, & Raben, 2003). Factors that interrupt continued exposure, i.e. distractors introduced during a meal or variety in food and sensory properties, delay the expected decrease in appetite (Brunstrom & Mitchell, 2006; Romer et al., 2006). This implies that, when a food is eaten, introducing another food with different sensory properties slows the decline in desire to eat the food and increases meal size.

Previous studies have shown that aromas may enhance perceived taste intensity (Frank & Byram, 1988; Schifferstein & Verlegh, 1995), and even perceived properties like thickness and creaminess (Bult, De Wijk, & Hummel, 2007), provided that the aroma matches the sensory property that is enhanced. The perceptual match between aroma on the one hand and taste and texture on the other hand is referred to as aroma-taste and aroma–texture congruency. Aroma-taste and aroma–texture congruency may be exploited to influence the perceived taste- and texture properties of a food without changing its macronutrient composition. Assuming that the total amount of exposure to a food's sensory properties defines the total decline in desire to eat, it is expected that an enhancement of sensory properties by a congruent aroma will further reduce desire to eat. Hence, two determinants of meal size may be distinguished, i.e. congruency of taste, mouth feel and aroma within one stimulus and variation in successive exposure to taste, mouth feel or aroma. Meal sizes may then be reduced by increasing the congruency of combinations of aroma, texture and taste or by reducing the sensory variation in successively presented foods.

The present study was designed to determine if the level of congruency and temporal variation in sensory input of aroma–texture combinations influence satiation and subsequent food intake. It was hypothesised that satiation and food intake are affected by the level of congruency as well as by variation of successive exposure to aroma–texture combinations. Hereto, panellists were presented with dairy products (i.e. custards) with a creamy texture, which contained aromas that were either congruent or incongruent with creamy texture. To control for possible effects of familiarity or liking of the used aromas with intake measures, aromas were used that had received different congruency ratings with respect to the product in which they were used, but similar liking and familiarity ratings. Using a regimen of a fixed preload followed by an *ad libitum* meal of the creamy custard, the effects of four possible aroma combinations on the amount of *ad libitum* food intake were tested in a two-by-two full-factorial design. Perceived satiation was measured throughout the experimental sessions on visual analogue scales (VAS). Salivary α-amylase concentration was measured as an alternative and more physiological measure of satiation (Harthoorn & Dransfield, 2008).

2. Materials and methods

2.1. Subjects

Thirty-two healthy women, aged between 20 and 40 years, participated in this study. They were recruited and screened for dietary restraint, eating disinhibition and hunger using a validated Dutch translation of the three-factor eating questionnaire (Stunkard & Messick, 1985; Westerterp-Plantenga, Rolland, Wilson, & Westerterp, 1999). Smokers and subjects with prescribed medication, except for contraceptives, were excluded from participating in the study. Subjects were paid for their involvement, and gave informed consent. Testing took place at NIZO Food Research (Ede, The Netherlands) in a laboratory setting by trained staff on four consecutive morning sessions of 1½ h each, from 8:15 a.m. to 9:45 a.m., with a minimum interval of 1 week between each session. All subjects arrived in a fasting state. Individual weight and height were measured while subjects wore indoor clothing and no shoes. The subjects were normal-weight subjects with a body mass index (BMI) varying between 20 and 25 kg/m^2, calculated as weight (kg) divided by height (m) squared.

2.2. Aromas

Five food-related aromas, i.e. vanilla (vanillin; 5 g/l), lemon (citral; 2.5 ml/l), strawberry (European COST 921 action; 2.5 ml/l), chocolate (3-methylbutanal; 2.5 ml/l) and buttery (2,3-butanedione; 2.5 ml/l), and two non-food-related aromas, i.e. rubbery (benzothiazol; 2.5 ml/l) and lavender (2,6-dimethyl-2-heptanol; 12.5 ml/l), were evaluated for their level of congruency with creamy texture as well as for liking and familiarity. Hereto, 51 panellists took a spoon full of the non-aromatised creamy custard while smelling the seven different aromas separately using dedicated flavour test strips (Aldrich, Zwijndrecht, The Netherlands). Subjects rated the congruency ("how well does this aroma fit with the custard?") of each aroma with the creamy texture of the custard and aroma-liking ("how much do you like this aroma?") and familiarity ("how familiar are you with this aroma?") using a 100-mm VAS labelled with "not at all" and "very much" at their ends. Of the aromas associated with foods, vanilla aroma was perceived as most congruent with respect to a creamy texture (Fig. 1) (2A02405, 2000 ppm) and lemon aroma was perceived as incongruent with respect to creamy texture (Fig. 1) (DU64668, 1000 ppm). Aroma concentrations were matched with regard to their subjective intensities in the custard.

2.3. Product preparation

Batches of non-aromatised creamy custard of 566 kJ/100 g were produced by Friesland Foods (Deventer, The Netherlands) and contained 90% milk, 3.1% starch, and 6.5% sugar, which corresponds to 7.6 (w/w)% fat, 14.1 (w/w)% carbohydrates, and 3.2 (w/w)% protein. Each batch was surveyed for microbiological safety and approved if appropriate according to the guidelines of the Dutch Food and Drug Act (VWS/VWA) and the European Directive 2073/2005. The two aromas were added to the creamy custard following a standard procedure of continuous stirring. Then the custards were left at 5 °C for at least 36 h before testing by the panellists, to allow a good equilibration of the aroma within the product.

2.4. Design and procedure

The subjects firstly consumed the fixed preload consisting of a 150 g portion (850 kJ) of either the vanilla- or the lemon-aromatised custard within 5 min, as illustrated in Fig. 2. Then, 15 min after finishing the preload intake, subjects were offered an *ad libitum* meal of 900 g of either the vanilla- or the lemon-aromatised custard, and were asked to eat of this portion as much as they would like until they felt pleasantly full. Congruency (high vs. low) and sensory variety in time of aroma–texture combinations were manipulated in a two-by-two full-factorial design. After *ad libitum* consumption, the left-over of the custards were weighed, and the amount of custard eaten was calculated. At eight specific time points during the test session, subjects were asked to rate their perceived satiation ("how satiated are you?") on 100-mm VAS, anchored at their ends by the descriptors "not at all" and "very much" (Fig. 2), as previously described (Flint, Raben, Blundell, & Astrup, 2000). In addition, after preload and after *ad libitum* consumption, subjects rated their liking for the product consumed ("how much do you like the product?") using 100-mm VAS with the descriptors "not at all" and "very much" at their ends (Fig. 2).