Can flavour enhancement modulate appetite and food intake in women?

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Abstract

Food flavour might be helpful for weight management by regulating appetite sensation and food intake. This chapter investigated whether the enhancement of flavour intensity or flavour complexity can modulate appetite sensation and food intake within a female sample. A single flavour modality, aroma or taste, seems to have no actual effect on appetite sensation and food intake. Sensory-specific satiety was developed for a flavour modality (sweet taste) after the consumption of a drink containing that flavour modality (sweet taste). An enhancement of flavour complexity due to multimodal interaction of two flavour modalities (aroma + taste) suppressed hunger sensation significantly but did not affect subsequent food intake.

Introduction

Excessive food energy intake has promoted the global overweight and obesity pandemic which accounts for approximately 9.1% of a country's total healthcare expenditure [1]. Food intake and appetite are mediated by successive satiation and satiety signals [2, 3]. "Satiation" is the process that results in the termination of a meal when appetite for food has been satisfied; "Satiety" describes the lingering feeling of satisfaction during the inter-prandial period before hunger returns [4]. To date, limited attention has been paid on the effect of food flavour which may act as a pre-ingestive satiation or satiety signal on the regulation of appetite and food intake [2].

Taste alone has been shown to contribute to the improvement of food palatability, resulting in an increase in hunger sensation and food intake [5-8]. On the contrary, a single flavour modality per se, aroma or taste, has been reported to enhance fullness sensation, suppress hunger sensation and reduce subsequent food intake [9, 10]. The preliminary findings from the current literature suggests that flavour can be appetizing due to its positive influence on food palatability, at the same time, a prolonged exposure to food flavour may also induce satiation or satiety signals over the time course of an eating event [9, 11]. A decrease in the palatability of a food after the food is consumed to satiation has been repeatedly observed, resulting in a reduction in subsequent consumption of foods with a similar flavour profile [12]. This phenomenon is described as sensory-specific satiety (SSS), which may partly contribute to the satiating effect of food flavour [12].

Aroma and taste modalities are two primary drivers in food flavour perception, but flavour perception is not a mere sum of the two modalities [13, 14]. Flavour is the synergistic combination of multisensory modalities; however, no study has been focused on the interactive effect of two flavour modalities on appetite and food intake. [13, 14]. This chapter investigated whether flavour enhancement can modulate appetite sensation and food intake. Flavour was enhanced in two dimensions: 1) a simple increase in the intensity of a flavour modality; 2) an increase in flavour complexity because of multimodal interaction. Specifically, two behaviour experiments were conducted to answer several unresolved questions in this field.

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Experiment 1: Whether enhancing the intensity of a single flavour modality (sweet taste) affected the ad libitum food intake and sensory-specific satiety;

Experiment 2: Whether two combined flavour modalities (aroma + taste) affected appetite sensation and subsequent food intake because of their multimodal interaction on flavour enhancement.

Experimental

Experiment 1

Protocol

The objective of this experiment was to study the effect of sweetness intensity of a milkshake on ad libitum intake of the milkshake and on SSS. Based on a cross-over experimental design, 24 female participants consumed one of the three pre-selected milkshakes with high sweetness (HS), ideal sweetness (IS) or low sweetness intensity (LS) over 3 sessions on 3 separate visits.

Having fasted from food and drink except water overnight (from 21.00 one evening before a visit), participants arrived at the laboratory at 8.45 in the next morning. Participants consumed 50 g porridge (190 kcal) ("So Simple Original Porridge Original Pot", Quaker Oat, UK) dissolved in 100 ml hot water as a standard breakfast between 9.00 and 9.20. From 9.20 to 10.25, participants fasted from any food and drink while sitting quietly in a waiting room. From 10.30 to 10.40, participants were served one of the milkshake (HS, IS or LS) with a serving portion of 800 ml to consume until they felt comfortably full. Participants were encouraged to ask for another portion of the milkshake if they needed. The volume of the milkshake consumed were recorded. The total energy intake of the milkshake was calculated by multiplying the volume (ml) consumed by its energy density (kcal/ml). Subjective appetite sensations were rated immediately before breakfast at 9.00 (baseline appetite), immediately before and after the consumption of milkshake using a 100-mm visual analogue scales (VAS) [15]. SSS was characterised by the changes (Δ) in the pleasantness of the milkshake after consumption of the milkshake, compared to the initial pleasantness of the milkshake. Immediately before and after intake of the milkshake, participants tasted and rated 5 ml of each of the HS, IS and LS milkshakes on the pleasantness of the milkshakes on a 100 mm VAS [11].

Participants and materials

24 recruited female participants had normal BMI with a mean of 20.2 ± 1.6 kg/m2. They were aged from 19 to 27 years (mean age: 22 ± 2 years), non-restraint eaters and not clinical depressed [16, 17].

The milkshakes, in every 100 ml, consisted of 50 ml mineral water (Evian, Danone Group, France), 50 ml of a commercial milkshake drink (Yazoo banana, Friesland Campina, Belgium), and varying concentrations of a low-caloric sweetener (Canderel Spoonful artificial sweetener, Merisant, UK). The HS, IS and LS milkshake samples were selected on an individual basis. Each participant tasted 10 milkshake samples with varying Canderel sweetener concentrations at 480, 576, 691, 829, 995, 1194, 1433, 1720, 2064 and 2477 mg. They rated their perceived intensities of sweetness, relative-to-ideal sweetness, pleasantness, and desire to drink the milkshake on 100-mm VAS scales. The geometric distance of the sweetener concentrations between each pair of HS and LS samples was similar between participants, which was 3-4 folds of the common ratio 1.2.

Experiment 2

Protocol

Using a "preloading paradigm" design, the impact of aroma and taste, in combination and independently, on appetite sensation and subsequent food intake were investigated. 26 female participants visited the laboratory 4 times to consume 4 different sample drinks as preloads, followed by ad libitum past meal. They were asked to fast from 21.00 at one evening before their visit until arriving at the laboratory next morning. During each visit, they arrived at 08.45 and baseline subjective appetite sensation was rated at 09.00 on a 100-mm visual analogue scales [15]. The appetite sensation include hunger, fullness, satisfaction, desire to eat and prospective consumption. Participants consumed a standardised breakfast containing cereal and milk between 09.00 and 09.20. At 11.00, they consumed one of the four sample drinks over 15 minutes using a fine straw (diameter: 0.625 mm, Altec Ltd., UK). VAS ratings were collected immediately at several time intervals before, during the 15 minutes' sample drink consumption, and until 65 minutes after the sample drink consumption. At 12.20, participants were provided an ad libitum pasta meal. They were given a 530 g (878 kcal) portion of pasta and instructed to terminate the meal only when they felt comfortably full. They were instructed to ask for another portion once the previous one was finished. The weight of the pasta consumed was recorded. Pasta energy intake was calculated by multiplying the weight (g) of pasta consumed by the energy density of pasta lunch (kcal/g). Participants seated in a quiet waiting room within the laboratory centre when not asked to conduct any experimental activity.

Participants and materials

The recruited 26 female participants had normal BMI with a mean of 20.9 ± 1.9 kg·m-2. They were aged from 18 to 45 years (mean age of 22 ± 4 years), non-restraint eaters and not clinical depressed [16, 17].

The 4 sample drinks were: water (S1, 150 ml, 0 kcal), water with 0.05% strawberry aroma (S2, 150 ml, 0 kcal), water with 8% sucrose and 0.1% citric acid (S3, 150 ml, 48 kcal) and water with 0.5% strawberry aroma, 8% sucrose and 0.1% citric acid (S4, 150 ml, 48 kcal). The volatile compounds in strawberry aroma (Mane Co. Ltd., Derby, UK) were ethyl butyrate, ethyl 2-methyl butyrate, and ethyl hexanoate, diluted in propylene glycol.

The breakfast consisted of Rice Krispies (Kellogg's UK Limited, Manchester, UK) and semi-skimmed milk (Sainsbury's Supermarkets Ltd., London, UK). It was equivalent to 10% of the participant's estimated total daily energy requirement and containing 14%, 14%, and 72% energy from fat, protein, and carbohydrate, respectively [18].

The pasta meal consisted of penne pasta, olive oil, cheddar cheese (Sainsbury's Supermarkets Ltd., London), and Dolmio Garden Vegetable pasta sauce (MARS Food, USA). Its energy density was 1.66 kcal/g, of which 14%, 52%, and 34% provided by protein, carbohydrate and fat, respectively.

Results and discussion

Experiment 1

Effect of sweetness intensity on ad libitum intake of milkshake

The hunger sensation reduced significantly after the consumption of milkshakes ($p < 0.05$), but appetite sensation was not affected by the sweetness intensity of the milkshake. The consumption amount (ml or kcal) of a high sweetness milkshake (HS) was not different from the intake of a less sweet milkshake (LS or IS), even when the two milkshakes shared a similar palatability (Figure 1 and Figure 2). It suggests that the *ad libitum* intake of the milkshake (satiation) was not affected by the sweetness intensity of the milkshake.

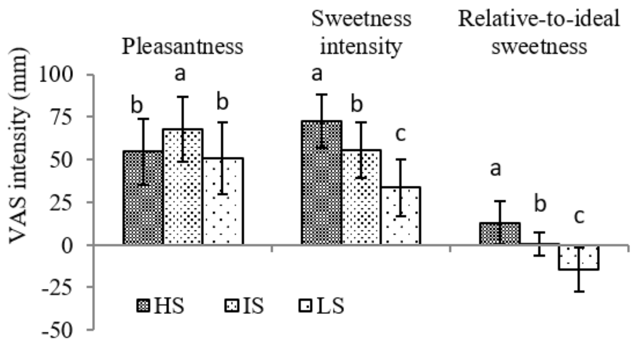

Figure 1: Mean (n=24) of the initial pleasantness, sweetness and relative-to-ideal sweetness for HS, IS and LS milkshakes. For each measurement, the samples without a same small letter were significantly different. Error bars represent the standard deviations

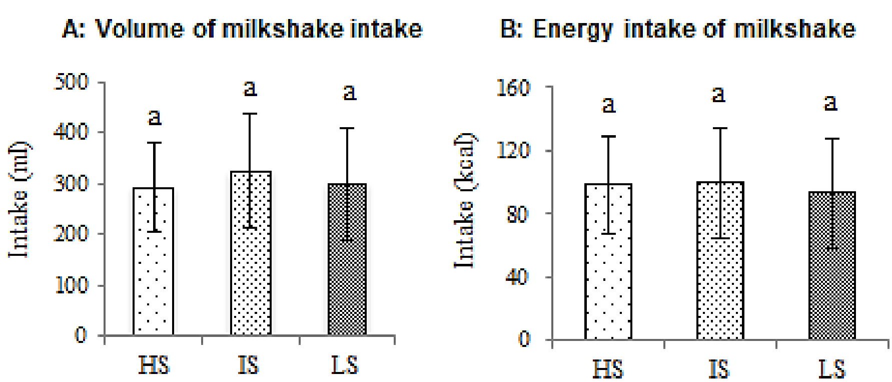

Figure 2: Mean values of *ad libitum* intake of HS, IS and LS milkshake samples measured as total volume consumed (A) and energy (B) consumed. Error bars represent the standard deviations. Values within a column without a same letter superscript are significantly different ($p < 0.05$)

Effect of sweetness intensity on sensory-specific satiety

The pleasantness of the HS milkshake was reduced significantly ($p < 0.05$), following the intake of the HS, IS or LS milkshake. This suggests that SSS for the HS milkshake was developed following *ad libitum* intake of any sweet milkshake. However, the reduction in the pleasantness of the HS milkshake was not affected by the sweetness intensity of the milkshake. This indicated that the extent of SSS for the milkshake was not affected by the sweetness intensity of the milkshake.

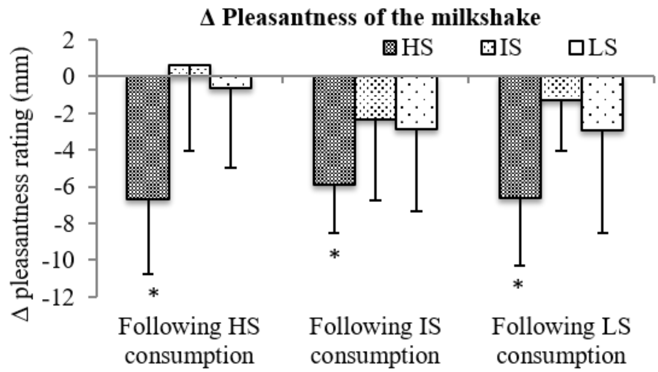

Figure 3: Change (Δ) in pleasantness of HS, IS and LS milkshakes. Δ pleasantness were calculated by subtracting the initial pleasantness ratings of the milkshake from the pleasantness ratings after consumption of the milkshake. Error bars are standard errors. '*' represents a significant reduction in the pleasantness. p< 0.05.

Experiment 2

Effect of combined aroma and taste on appetite sensation

The consumption of the sample drinks containing only aroma (S2) or only taste (S3) did not affect appetite sensation differently from the water control (S1) (Figure 4) [19]. But the combined aroma and taste (S4) suppressed hunger sensation more than the water control (S1) or the sample drink with only aroma (S2) or only taste (S3), during the 15-min sample drink consumption. The drink condition with combined aroma and taste (S4) suppressed hunger sensation more than the water control (S1), the aroma condition (S2) and the taste condition (S3) for a further 30 minutes, 20 min and 5 minutes after the sample drink was consumed, respectively ($p < 0.05$). This suggests that the combined aroma and taste induced a greater satiation and a greater short-term satiety than aroma, taste and the water control. This was potentially due to an increase on the perceived intensity of flavour and an enhancement of the complexity of the perceived flavour because of aroma-taste cross-modal interaction [19].

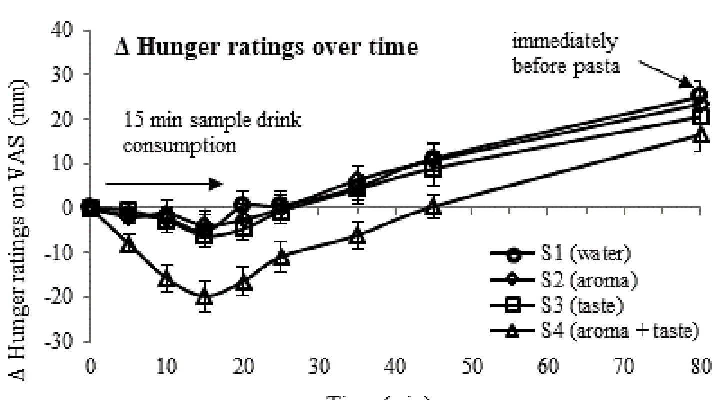

Figure 4: Mean Δ hunger over 5, 10, 15, 20, 25, 35, 45, and 80 min after starting to consume sample drink of S1 (water), S2 (aroma), S3 (taste) or S4 (aroma + taste), n = 25 participants. Error bars represent standard errors [19].

Effect of combined aroma and taste on subsequent food intake

The subsequent energy intake of the pasta meal, provided 65 min following the sample drink consumption, was not different by the different sample drink preloads (Table 1) [19]. The accumulative energy intake did not differ between the sample drink conditions.

Table 1: Mean ± standard deviation (n=26) of energy intakes from pasta meal and accumulative energy intake of pasta and sample drink in the 4 sample drink conditions [19].

Sample drink conditions	*Pasta meal energy intake (kcal)*	*Accumulative (sample + pasta) energy intake (kcal)*
S1	776 ± 96 [a]	776 ± 96 [a]
S2	781 ± 75 [a]	781 ± 75 [a]
S3	759 ± 82 [a]	807 ± 82 [a]
S4	757 ± 89 [a]	806 ± 89 [a]

Values within a column without a same letter superscript are significantly different ($p < 0.05$)

Conclusion

A single flavour modality, aroma or taste, had no actual effect on appetite and food intake. The consumption of a drink containing one flavour modality (sweet taste) induced sensory-specific satiety for that flavour modality (sweet taste). However, increasing the intensity of a single flavour modality did not affect appetite sensation, food intake and sensory-specific satiety. An enhancement on the flavour complexity due to the multimodal interaction of two flavour modalities (aroma + taste) suppressed hunger sensation significantly but did not affect subsequent food intake.

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