Aroma induced satiation

Possibilities to manage weight through aromas in food products

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ABSTRACT: FOOD INDUSTRIES ARE LOOKING FOR NEW FOOD PRODUCTS THAT COMBINE LIKING WITH LIMITED FOOD INTAKE DUE TO ENHANCED SATIETY SIGNALS. THIS SHOULD LEAD TO INCREASED FEELINGS OF FULLNESS DURING OR IN BETWEEN MEAL CONSUMPTION. BY DEVELOPING FOOD PRODUCTS WITH THIS ADDED VALUE, THE FOOD INDUSTRY IS ABLE TO TAKE PART OF ITS SOCIAL RESPONSIBILITY IN ADDRESSING THE OBESITY PROBLEM. NIZO FOOD RESEARCH IS EXPLORING THE ROLE OF AROMA IN SATIETY MECHANISMS USING ITS STATE-OF-THE-ART OLFACTOMETER TO CAREFULLY ADMINISTER AROMA STIMULI TO THE CONSUMERS UNDER STUDY. BY BEING ABLE TO ADMINISTER AROMA PROFILES SEPARATELY FROM OTHER STIMULI (SUCH AS DIFFERENT INGREDIENTS, TEXTURES AND TASTES), NIZO FOOD RESEARCH HAS THE OPPORTUNITY TO INVESTIGATE THE RELATIVE IMPORTANCE OF AROMA STIMULI FOR SATIETY.

SEARCH FOR SATIETY TRIGGERS

The rapid increase in the prevalence of overweight and obesity and associated co-morbidities are a major global health problem.
In addition to these health risks, obesity is often accompanied with psychological and social problems, as well as a reduced quality of life (1-4). Energy imbalance is considered the main cause of obesity (5). To provide energy balance, conventional weight management (dietary intervention, physical activity, behavioural therapy) often results in short-term successes, but sustained weight maintenance is difficult to achieve (6). Hence, alternative weight-reduction strategies might contribute to a solution. Multiple academic and industrial efforts are underway to find strategies to reduce obesity.
For instance, in 2005 a large EC funded project started called DiOGenes (an acronym for Diet, Obesity and Genes) which main objective is to reduce overweight, obesity and its co-morbidities in Europe facilitated by an expanded knowledge base, which will generate the tools to optimise dietary intake for prevention of weight (re)gain for different types of consumers (7).
Evaluation of food characteristics on satiety is part of the DiOGenes project; here NIZO food research is involved in understanding the role of aroma in satiety mechanisms. Since recent years, the food industry is spending a large amount of effort in developing low fat and low calorie products with an aroma and texture that are as good as regular products.
As an example, the release of aromas from reduced-fat matrices during consumption can be measured and adjusted using atmospheric pressure chemical ionization-mass spectrometry (APcI-MS) technology (8-11).

In Figure 1 this is illustrated for a dairy product like yoghurt. The flavour release of an arbitrary (lipophilic) aroma compound is highly dependent on the amount of fat present in the food matrix as well as the type of fat. Lowering the fat content will result in a striking increase of the release of this aroma compound while on the other hand an alternative type of fat will almost prevent the aroma compound to be released from the yoghurt during actual consumption. Clearly, these three different food matrices affect the *in vivo* flavour release of aroma volatiles and thus the final sensory perception of the products. Typically, these types of studies are used to optimise the taste and aroma perception of reduced fat consumer products. However, the ultimate aim is to develop a good tasting low fat product that also induces an increased level of satiety which will prevent consumers to overeat. The triggers may act in different phases of the "satiety cascade", a framework which describes the mechanisms and processes that take place during consumption, digestion and absorption of a food product (12).

In Figure 2 this "satiety cascade" is depicted along the meal intake cycle (12, 13). In most cases active ingredients incorporated into food products are aimed at later phases of the "satiety cascade" e.g. in the post-ingestive and post-absorptive stage. In the current work of NIZO food research special focus is on the possibility of using sensory triggers and in particular aroma for inducing or increasing satiation (14-16). These sensory triggers take part in the early phases of the satiety cascade at the interface between satiation and satiety, contributing to the process of meal termination.

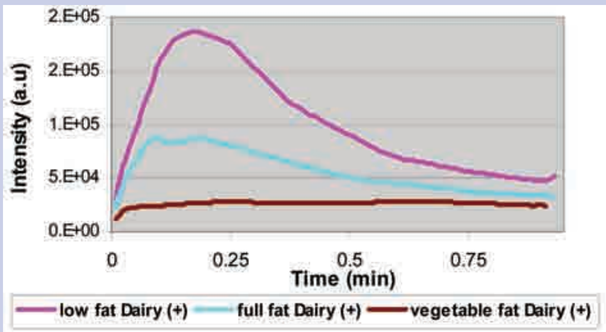

Figure 1. Example of average in vivo flavour release curves of a lypophilic aroma compound as measured from three dairy products with differences in fat. On the horizontal axis the time is sited while on the vertical axis the amount of flavour release as measured by the APcI-MS is to be found. The light blue curve is from a regular full fat product (3 percent), while the pink is from the same product at low fat (0 percent). The brown curve is from a comparable dairy product with supplemented with vegetable fat (3 percent) has to be changed into the brown curve is from a comparable dairy product supplemented with vegetable fat (3 percent)

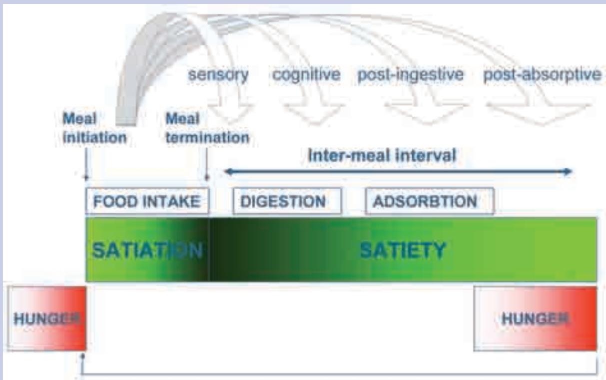

Figure 2. Schematic overview of a food intake cycle and satiety cascade with related terminology (adapted from 12, 13).

SENSORY STIMULATION (RETRO-NASAL AROMA RELEASE)

During the consumption of a meal, aroma molecules either reach the olfactory epithelium orthonasally (perceived as originating from the external world) or retro-nasally (perceived as arising from the mouth) (17, 18). The brain response, i.e. neural brain activation to a retro-nasally sensed food odour is signalling the perception of food (19). The latter is hypothesised to be related to satiation, i.e. sensory-related satiation. There are indications that not all food types result in the same quality (flavour) or quantity (intensity) of sensory stimulations (20-22). Differences in structure and composition of the food may be (partly) responsible for this effect.

From previous work at NIZO food research (23) and other groups, it is known that the physical structure of a food that is consumed is important for the extent of retro-nasal aroma release during consumption, i.e. solid foods generate a longer, more pronounced retro-nasal aroma release than liquid foods (Figure 3) (24-27). This difference in retro-nasal aroma release could be one of the reasons that people are more satiated by a solid food compared to a beverage (30-33). Additionally, interpersonal differences are important for retro-nasal aroma release efficiency. These are factors that are likely uncontrolled by a person, e.g. saliva production, nasal anatomy and oral processing habits (34-38).

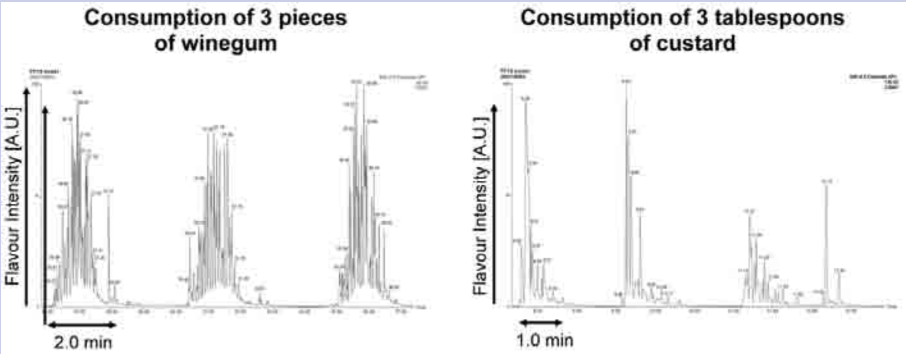

Figure 3. Example of one subject, taken from reference 28, illustrating the differences in the extent of retro-nasal aroma stimulation between the consumption of three times one mouthful (on average 5 g per mouthful) of winegum ((soft) solid food) and three times one mouthful (on average 19 g per tablespoon) of custard (liquid food), measured by in vivo APcI-MS technology (8, 29). As appears from the triplicate measurement, people are reproducible in the morphology and intensity of their aroma release profile

UNIQUE TOOLS

In order to be able to study the effects of olfaction on satiation, tailored olfactometer equipment has been developed which is able to deliver specific well-defined flavour profiles to the subjects (Figure 4). The ability to administer aroma stimuli separately from other stimuli (such as different ingredients, textures and tastes) enables investigating the relative importance of aroma stimuli for satiety. As already described by Visschers et al. (39), delivering food-related aroma stimuli via an olfactometer to subjects involves a variety of parameters and matching the aroma stimuli to such a level that can be genuinely related to food is a complex process. The approach that is used is based on the knowledge of measuring aroma release *in vivo* in real time using APcI-MS (8-11). It has been demonstrated that indeed the aroma profile that is generated with the olfactometer closely resembles the concentration of volatiles in the nose space measured for an individual subject eating or drinking a specific product. This enables the design of complete aroma release profiles that mimic those obtained by *in vivo* experiments during the consumption of foods (39).

Figure 4. Tailored Burghart OM 4 four-channel monorhinal olfactometer set-up

PROOF OF PRINCIPLE

Sensory stimulation by aroma might be affected by intensity, duration and complexity of the aroma stimuli (24-26, 40). Within the DiOGenes project NIZO food research is studying these different aspects of aroma in relation to perceived satiation and actual food consumption.
Recently, NIZO food research has investigated if a beverage becomes more satiating when the retro-nasal aroma release profile coincides with the profile of a (soft) solid food (41). In a double-blind placebo-controlled randomised cross-over full factorial design, twenty-seven healthy subjects (14 males/13 females; aged 16-65 years; body mass index (BMI) 19- 37 $kg \cdot m^{-2}$) were administered aroma profiles by a computer-controlled stimulator based on air dilution olfactometry. Profile A consisted of a profile that is obtained during consumption of normal beverages. Profile B is normally observed during consumption of (soft) solids. The two profiles were produced with strawberry aroma and administered in a retro-nasal fashion, while the subjects consumed a sweetened milk drink. Before, during and after the sensory stimulation, satiation measurements were performed. A significant difference was demonstrated in perceived satiation between perceived satiation after an olfactometer delivery of a classical beverage aroma profile compared to the perceived satiation after an olfactometer delivery of a soft solid aroma profile. As turns out from Figure 5, during aroma stimulation subjects felt significantly more satiated if they were longer aroma stimulated ($F = 4.24$; $P = 0.04$).

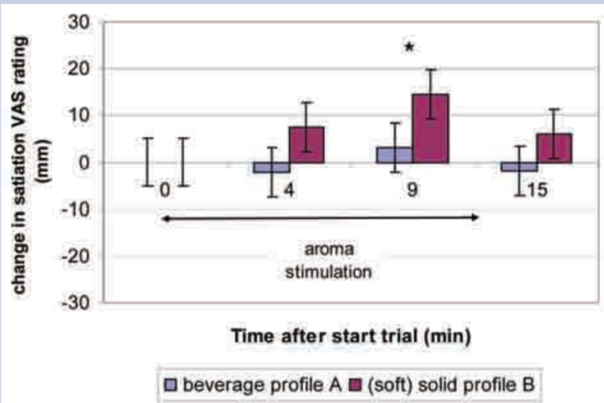

Figure 5. Change in satiation VAS ratings after stimulation with aroma profile A vs. aroma profile B. Data are means with their standard errors represented by vertical bars. * denotes effect of type of aroma stimulation (profile A or B) on change in satiation VAS rating with $p < 0.05$ (41)

Despite changes in subjective experience, there was no impact on ad *libitum* amount consumed. However, in a follow-up study it would be a great challenge to obtain also a significant effect on actual food intake. In conclusion, perceived satiation was increased by altering the extent of retro-nasal aroma release (41).

OPPORTUNITIES

The contribution of aroma in inducing satiety seems very promising and appealing but the current state-of-the-art in this field of research is still preliminary. The results of above-mentioned study are promising for the development of novel health foods that contain multiple triggers that are able to induce or increase the feeling of satiation. While active ingredients may induce satiety at later stages in the food intake cycle, sensory triggers operating at early stages have a consumer benefit that is immediately noticeable. For instance:

- foods with an increase of aftertaste by lingering aroma,
- specialised aroma encapsulations residing longer in the mouth cavity, or
- long chewable food structures that evoke lots of oral processing and an increase in transit time in the oral cavity, resulting in a higher retro-nasal aroma release efficiency.

These applications may lead to a higher quality and/or quantity of sensory stimulation, which in turn may lead to enhanced feelings of satiation. For example, people who are participating in a weight loss program may benefit by these foods. Usually, they keep on a calorie-restricted diet and during the day they are struggling with feelings of hunger and desire to eat. It would be much easier for them to comply with that calorie-restricted diet if the diet contains (multiple) triggers that would induce a feeling of satiation. Generally, motivational state is an important consumer benefit. When a product is perceived as inducing a feeling of satiety, the consumer feels good, just by consumption of the product on itself. This would be the ultimate selling point for food industries.

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