The role of intense sweeteners on appetite and satiety

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Appetite and satiety

• Important aspects of the control mechanisms that determine food intake
• They should contribute to the body energy balance by stimulating intake in response to needs and inhibiting intake when needs have been met
• In addition to physiological signals of need, both appetite and satiety are sensitive to factors (e.g. sensory stimulation, environmental cues, etc.) that have little to do with physiology
100 %behaviour

Energy (calories)

Nutrients

Daily intake patterns

% energy expenditures

100

Other 2-3

DIT 8-12

PA 15-30

BMR 60-70

BAT Thermogenesis

Foods

Intensity Duration

Age Gender Genetics Lean Mass

Intake

Expenditures

ENERGY BALANCE

ENERGY BALANCE

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Appetite

• Broad concept associated with the acceptance of foods and willingness to ingest them
• Affected by many factors, among which is palatability: sweetness is a strong stimulant of appetite (« Liking », « Wanting »)
• Substances that confer sweetness are likely to stimulate intake in many circumstances (hunger states corresponding to physiological need, or eating in the absence of hunger in response to hedonic mechanisms)
• Sugars and intense sweeteners are such substances
Satiety

• Satiety is a state of repletion consecutive to intake that inhibits further consumption until the return of hunger.

• It varies according to numerous factors: total energy load and density, nutrient content (protein > CHO > fat), sensory, cognitive, physiological, environmental, and other influences can enhance or decrease its intensity or duration.

• Many factors may stimulate intake in the absence of hunger, overruling physiological or other satiety signals.
The Satiety Cascade
Sweetness and appetite

- Sweetness contributes to the palatability of many foods and drinks and facilitates their acceptance.
- Sweetness stimulates intake, particularly in children and elderly consumers.
- There are large individual differences in liking for sweet foods and drinks.
- Sweetness is traditionally associated with sugars that bring 4 kcalories per gram and contribute to the daily energy intake; energy and CHO contribute to post-ingestive satiety.
- Sweetness can also be obtained by using intense sweeteners that confer the palatable taste without the energy load (no energy, no CHO: less satiety?)
Intense sweeteners, appetite, satiety and intake

• Intense sweeteners make it possible to uncouple the pleasant sweet taste from the energy load (4 kcal/gram)

• Theoretically, this might be a good idea, as it could allow consumers to enjoy their preferred sweet foods without the energy intake associated with sugars

• In fact, a few questions have to be asked:
  – Will this affect energy intake? In what direction?
  – Will this affect body weight control?
  – Can this exacerbate the « liking » and « wanting » of sweet-tasting substances?

This is a complex issue.
How does replacing sugars with intense sweeteners affect appetite and satiety factors?
Importance of the food/drink context
A few examples

<table>
<thead>
<tr>
<th>Product (100 g)</th>
<th>Sugar containing (kcal)</th>
<th>With intense sweeteners (kcal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soda</td>
<td>40</td>
<td>2</td>
</tr>
<tr>
<td>Fruit drink</td>
<td>56</td>
<td>11</td>
</tr>
<tr>
<td>Low fat yoghurt</td>
<td>75</td>
<td>44</td>
</tr>
<tr>
<td>Chocolate</td>
<td>513</td>
<td>510</td>
</tr>
</tbody>
</table>
Intense sweeteners in solid foods

- Intense sweeteners can replace sugars in solid foods in order to obtain a pleasant sweet taste.
- The energy content and energy density of the final product depend on its actual composition. It might not be very different from the original sugar-containing product.
- The decrease in sugar content may not correspond to a decrease in energy content or density or even in CHO content.
- Therefore, there is little reason to expect satiety and later intake to be affected in a significant way.
Intense sweeteners in drinks

• Sugar can be totally replaced by intense sweeteners in drinks so that the final mass of the drink is water (for example in sodas)

• This represents a large difference in energy content

• Will the consumer “compensate” for the “missing” energy?
The issue of energy « compensation »

• Will the organism realise that some energy is « missing » when sugars are replaced by intense sweeteners?
• Will it « compensate » (or even “overcompensate”) for it?
• Many tests of this under laboratory settings
The « pre-load » paradigm

Under laboratory settings, « compensation » has been studied using an experimental paradigm with successive steps:

• First, a « pre-load » is ingested, containing either sugar, or an intense sweetener (a drink, a yoghurt, etc.)

• After a delay (from 20 min to a few hours), a meal is consumed *ad libitum*. Intake is measured.

• Pre-load energy + meal energy = ???????

• Is there any energy adjustment of meal intake in compensation for the pre-load energy?
The pre-load paradigm

Pre-load A

Variable delay
20 min -- <3h

Pre-load B

Meal

Meal

Ad libitum Intake is measured
Is there « compensation » or adjustment for the energy ingested at previous eating occasions?

• Sometimes (depending on many factors, such as age, gender, delay between eating occasions, type of food or drink, etc.)

• When compensation does occur, it is generally imprecise (total energy intake is somewhat lower when intense sweeteners are substituted for sugars)
The special case of energy obtained from drinks

- Sugar-containing drinks can easily add up to an important energy load, while the consumer has no awareness of such intake (« passive overconsumption »; “low satiety power” of drinks)

- It is debated whether intake of energy-containing beverages elicits adequate dietary compensation (for example, Bray 2004; Mattes 1996). Energy from drinks seems to simply add to habitual energy intake from solid foods and does not trigger compensatory decreases in solid food intake (de Castro 1993; Fantino 2004)

- Again this is a complex problem and responses to energy-containing fluids depend on many factors. It seems likely that energy (sugar) removed from drinks will not be compensated for by increased solid food intake
Sweetness with inconsistent metabolic consequences: a rat model

- After young rats are exposed to both energy containing (sucrose) and non-energy containing (saccharin) solutions, overeating follows intake of a sweet beverage and increased weight gain is observed over 5 wks (Swithers & Davidson 2008).

- Unclear how this could extrapolate to human dietary situation.

- People who consume diet beverages without concurrent energy intake, at least occasionally, do not show any sign of heightened appetite or energy intake after such consumption (Appleton & Blundell 2007).
Grocery purchase patterns of diet soda buyers
(Binkley & Golub, 2007)

• Records of all food products purchased
• N=1574 individuals living alone
• Diet soda prone consumers made better nutrition choices
• No indication that the use of diet sodas might induce compensation by increased consumption of high-energy foods
Dietary intake associated with use of intense sweeteners
The SuViMAX study
(Bellisle et coll, 2001)

- A large-scale (12000 subjects) longitudinal study of free-living French adults.
- Some were regular consumers of intense sweeteners.
- They were heavier than peers who were not consumers of intense sweeteners.
- Their daily diet brought:
  - Less energy (their appetite did not appear to be particularly stimulated by intense sweeteners).
  - Less sugar (they did not show any sign of enhanced « liking » or « wanting » for sweet products).
Meta-analysis including randomised controlled trials with:

• Assessment of intake for at least 24 hours (16 studies)
• Replacing sugars by intense sweeteners is associated with a decrease of the daily energy intake (about 10%)
A few words on « cognitive » determinants

• In free-living situations, consumers know whether they are ingesting products containing intense sweeteners.
• Is this likely to modify their appetite and satiety responses to these products?
• In what way?
• Subjects informed that they are eating “diet” or “low sugar” foods might eat more at the next occasion (Mattes 1990).
• This could counteract the potential efficacy of intense sweeteners as an aid in intake control.
Intense sweeteners and development of «liking» for sweet products
(Mahar & Duizer, 2007)

• Sensory evaluation tests in 64 healthy women
• Frequent users of intense sweeteners showed the same level of appreciation for sweet-tasting fruit juice as frequent consumers of sugar
• No indication appeared that the frequent use of intense sweeteners might enhance appetite for sweet-tasting substances.
Peripheral mechanisms affecting appetite and satiety
Physiological effects of intense sweeteners on satiety

- Intense sweeteners vary in their chemo-physical nature
- Their constituents could physiologically affect satiety, e.g. satiety effect of the di-peptide aspartame when ingested in capsules (Rogers et al.)
- In everyday like circumstances, intense sweeteners are ingested in foods or in association with foods and their contribution to the final nutrient load is likely to be modest.
Intense sweeteners and insulin secretion

• Several studies have established that
  – The intake of a drink containing intense sweeteners does not trigger a reflex, cephalic-phase, secretion of insulin (e.g. Smeets et al 2005)
  – The intake of foods containing intense sweeteners triggers an insulin response that depends on the nutrient composition, plus an eventual « cephalic phase » secretion
Central mechanisms affecting appetite
Intense sweeteners and brain activity
(Smeets et al, 2005)

• Functional Magnetic Resonance Imaging study (n= 5 healthy men)
• Four stimuli: water, glucose solution, aspartame solution and maltodextrine solution
• The activity of the hypothalamus is modified only by the ingestion of glucose
• No effect of other solutions
• The sweet taste of aspartame does not induce the same hypothalamic response as that of sugar.
Intense sweeteners and brain activity
(Frank et al., 2008)

• Functional Magnetic Resonance Imaging study (n=12 healthy women)
• Solutions of sucrose or sucralose
• Both stimuli activate primary taste pathways
• Then, brain responses vary
• Sucrose activates dopaminergic midbrain areas associated with pleasure responses
• The brain thus seems capable of discriminating between sweet-tasting solutions that contain or do not contain energy.
Conclusions

- Intense sweeteners have been used in foods and drinks for several decades.

- No « magic effect » on energy intake:
  - Substituting sugars with intense sweeteners does not necessarily induce a significant change in energy or nutrient content of foods; therefore no or little effect on satiety should be expected.
  - In drinks such as sodas, it is doubtful whether any “compensatory” mechanism operates to adjust intake for the absence of energy in diet drinks.
  - Cognitive effects are important: consumers of “diet” foods and drinks tend to integrate this behaviour in a pattern of healthy food choices (as shown in French and American consumers).
Conclusions

• No confirmation that intense sweeteners might exacerbate appetite for sweet products (a commonly expressed view in France)

• The sweet taste of intense sweeteners appears to be discriminated from that of energy-containing sugars by the brain, especially in areas influencing intake and appetite