SUGAR AND MODERNITY
in Latin America
Interdisciplinary Perspectives

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Sweetness Preference, Sugar Intake, and Obesity in Latin America

By Ulla Kidmose and Heidi Kildegaard

Taste is a very important determinant for food intake: if you like the taste of the food you will eat it! The sweet taste of sugar often contributes to high liking and food preferences. Children are born with a high sweetness preference due to the sweet taste of breast milk, but there are many other factors besides this preference that may affect sugar intake and the onset of obesity. The relationship between sweetness perception, high liking and preference of sweet food and sugar intake as well as obesity is elucidated in this chapter.

The sensory quality of food is evaluated by humans using their five senses: i) the gustatory sense (the sense of taste), which is situated on the surface of the tongue and the palate in the mouth; ii) the olfactory sense (the sense of smell) in the nose; iii) the sense of vision in the eye; iv) the sense of hearing in the ear; and v) the sense of touch on the surface of skin. The sense of taste is a chemical sense, since chemical compounds are registered by the taste buds on the tongue and the soft palate in the mouth. On the tongue four classical basic tastes are detected: sweetness, bitterness, sourness, and saltiness. Additionally, umami is counted as the fifth taste (Lawless & Heymann 1998). Taste buds are clustered in groups of 30-50 cells, forming balls or onion-shaped structures. Pores on the top of the taste buds connect them to the fluid environment of the saliva in the mouth. Following the ingestion of food, taste molecules are dissolved in the saliva and the pores situated on the taste buds detect these molecules. From the taste buds, gustatory signals are transmitted to peripheral nerves which transmit taste sensation signals to the brain (Meilgaard et al. 2007). During this process, a specific taste quality perception is generated allowing sugars to be differentiated from other compounds in foods. Hence,
the term 'sensory perception' designates the act of becoming aware of a stimulus and its qualities.

Sensory perceptions are created by both the sensations that are triggered and the brain's interpretation of these sensations. The interpretation of sensations is often based on previous experience. Hence, sensory perception involves chemical and physiological reactions in combination with human psychology and it varies between individuals.

Perception of taste intensity allows the taste buds to detect different concentrations of sweet tasting compounds, but due to individual differences in taste perception, it is not possible for anyone to determine the absolute concentration of a sweet tasting compound (Lawless & Haymann 2010; McCaughhey 2008; Meilgaard et al. 2007). The lowest concentration of a substance such as sucrose or the minimum intensity required for detection of a sweet stimulus is defined as the absolute threshold value for sweetness. Threshold values of sweetness vary between individuals due to factors such as age, gender, and illness and are strongly associated with how sweet a product is expected to be. Meilgaard et al. (2007) examined the threshold values for sucrose in 47 individuals and found that the range of the threshold values for sucrose varied between 0.08g/100mL and 2.56g/100mL.

Many studies have shown that children have lower taste sensitivity than adults (Glanville, Kaplan, & Fischer 1964; James, Laing, & Oram 1997; Mela 2001), though a few studies have reported that children aged 5-7 and 8-9 years have detection threshold values similar to that of adults (Anliker et al. 1997; James et al. 2004). This lower sensitivity means that children simply require higher levels of e.g. sweetness in foods to achieve the same perception of sweetness intensity experienced by adults. Zandstra and de Graff (1998) showed that with increasing sucrose concentration the perception of sweetness increased by a lower gradient in children aged 6-12 years compared to older children and adults. It is also known that as people get older the threshold of stimuli needed to excite taste sensations increases (Meilgaard, Civille, & Carr 2007; Mojet, Christ-Hazelhof, & Heidema 2001). In a study by Mojet, Christ-Hazelhof, and Heidema (2001), the detection thresholds for several tastants were determined for 21 young and older men and women, respectively. They found an overall effect for age as well as a gender-age interaction for detection thresholds of sucrose: older men were less sensitive to sweetness than young people, and tended to be less sensitive than older women. These results indicate that changes occur in taste sensitivity and hence sweetness perception across life span.
SWEET TASTE AND SWEET COMPOUNDS

To be perceived as sweet after ingestion, food molecules need to fit into specific receptors situated on the taste buds on the tongue. Simple sugars, which are perceived as sweet, include sucrose, fructose, glucose, galactose, lactose, and maltose. In both sugar beet root and sugar cane, sweetness is due to the presence of a high content of sucrose as described in detail in “Production methods and quality of sugar cane in Latin America” (Bjoern & Kidmose 2013). Other compounds that also have a sweet taste include inulin, which is present in high quantities in Jerusalem artichokes, many alcohols like xylitol and sorbitol glycerol, and steviosides, which originate from the leaves of the South American plant Stevia rebaudiana. In recent years, new sweeteners such as aspartame and acesulfam K have been manufactured; many of these synthetic sweeteners have a very high intensity of sweetness compared to sucrose (Cardello et al. 1999; Cardoso & Bolini 2007).

Assessment of the relative sweetness of different sugars or sweet compounds is rather difficult since the perception of sweetness is individual. In general, methods used to determine relative sweetness intensity include paired comparisons, the constant stimulus method, and magnitude estimation (Cardello, Da Silva, & Damasio 1999). Using these methods, potency (defined as the number of times sweeter a compound is than an iso-sweet concentration of sucrose) can be assessed. The sweetness potency of stevioside and aspartame are 160 and 100-200, respectively, whereas the potency of glucose and fructose are slightly lower and higher than sucrose, respectively. Sweetness potency depends on the concentration of sucrose, pH, and temperature.

SWEETNESS, PREFERENCE, AND LIKING

Sensory analysis encompasses both objective and subjective sensory evaluations. The subjective sensory evaluation includes consumer tests. These are affective tests, a general class of sensory tests that assess the acceptability or degree of liking of a set of food products. When discussing subjective sensory evaluation by consumers, we use two key terms: Liking and preference. Consumers’ liking and preferences are measured or assessed using two different methods. Liking or acceptance of food can be evaluated using a rating test. In hedonic rating tests, products are evaluated on a line scale or an interval scale and the food is evaluated according to how much it is liked. Hedonic
scales may be 9-point, 7-point, or 5-point scales. They allow the participant to express positive, indifferent, or negative reactions, as shown in Figure 1.

![Figure 1. A smiley 7-point hedonic scale (Kildegaard 2011).](image)

The term *preference* is also used in relation to consumer tests and refers to an individual’s preference for one product over another. In general, preference tests do not use hedonic scales but rather ranking tests. In a ranking test, two or more products are compared according to preference. Individuals are asked to rank products in either descending or ascending order of preference, as shown in Figure 2 (Kildegaard 2011). However, these tests are not very informative about the magnitude of liking or disliking of the product since preference does not necessarily reflect liking. One product may be preferred over another without being liked at all (Lawless & Heymann 2010). In consumer science and physiology, the term preference is often used instead of liking.

![Figure 2. An example of a ranking test. The consumers were served 5 food products, each with a 3-digit code and after tasting the samples they were asked to rank the products from most to least liked by writing the 3-digit codes in the boxes (Kildegaard 2011).](image)

In general, both food preference and liking are very subjective terms and depend very much on the individual. Personal factors form a significant part of taste perception, as described in the section “The sweet taste, sensitivity, and perception.” The individual’s unique perception of a food will have an influence how much they like it. Earlier it was assumed that sweetness percep-
Figure 3. Overview of factors influencing children’s food preferences and food choices (Kildegaard 2011; adapted from Shepherd & Pro-children framework 1989).

Liking is one of the major determinants for food intake, food choice, and eating habits. Several studies have shown that children’s liking is highly predictive of their intake (Birch 1979; Birch & Sullivan 1991; Gibson, Wardle, & Watts 1998). Moreover, cultural, sociological, social, and individual factors, such as physiological factors, age, gender, and attitudes, affect our food preferences, liking, and eating behaviour (Fig. 3) (Kildegaard 2011; Birch 1999; Reed et al. 1997; Drewnowski 1997; Nicklaus et al. 2004).

The development of human preferences and liking is a result of the interaction between genetic predispositions and environmental and learned factors (Birch 1999). Infants have an innate preference for sweet tastes and they prefer sugar solutions to water and sweeter solutions to less sweet solutions, in contrast to adults (De Graaf & Zandstra 1999; Desor, Maller, & Turner 1973; Nisbett & Gurwitz 1970). The innate preference for sweet tastes can be
ascribed to the fact that infants are adapted to the sweet taste of breast milk immediately after birth. Moreover, sweet foods are in general safe foods, in contrast to bitter tasting foods; bitterness is often a result of a high content of toxic compounds (Holt et al. 2000).

CHANGING THE PREFERENCE AND LIKING FOR SWEETNESS

Studies have shown a decline in sweetness preference as children become adults that may be caused by a shift in taste sensitivity of sweetness (Desor & Beauchamp 1987; Nicklaus et al. 2004). It is observed that children live in a different chemical sensory world from adults, as evidenced by their higher preference for sweet and sour tasting foods (Darwin 1877). In addition, preference for and liking of sweet tastes can be modified through repeated exposures to these tastes (Liem & Graaf 2004; Beauchamp & Moran 1984; Holt et al. 2000). A study in which infants were repeatedly exposed to sweetened water showed that at two years of age these infants had a high preference for sweeter-tasting water (Beauchamp & Moran 1984). Liem and de Graff (2004) showed that when both children and adults experienced repeated exposure to sweet orangeade with added sucrose, only the children developed a significantly increased preference for sweet orangeade after the exposure period. These children also tended to consume more orangeade during the last day compared to the first day of intervention.

In contrast, the preference for sweet orangeade did not change in the adult participants; they consumed significantly less during the last day compared to the first day of intervention (Liem & de Graaf 2004). In a study by Sartor et al. (2011), normal-weight adult subjects were divided into sucrose-likers and sucrose-dislikers before a four-week soft drink supplementation period (≈760ml soft drink/day). Only the sucrose-dislikers significantly increased their preference towards sweetness after the soft drink supplementation period; the sucrose-likers did not experience any change.

In summary, alteration of sweetness preference after repeated exposure to sweet food can occur, but several factors such as age and initial sweetness preference influence the effects of repeated exposure.

PREFERENCE AND LIKING FOR SWEET TASTES AND SUGAR INTAKE

As described in the previous section, many children have a high preference for sweet tastes. Several studies have shown that a high preference for sweet
tastes has a strong correlation with a high consumption of sugary foods (Cooke & Wardle 2005; Pangborn & Giovanni 1984; Holt et al. 2000). Many sugary foods are associated with a high energy density, and consumption of high energy-dense foods may contribute to disruption of the body's energy balance, causing obesity. Duffy et al. (2003) explored whether markers of taste variation were associated with variability in sweetness sensation, sweetness preference, and intake of added sugar. They used 6-n-propylthiouracil (PROP) and quinine hydrochloride (QHCL) to predict sweetness in solutions and foods since perceived bitterness of PROP and quinine has been shown to correlate with sweetness preference. By using multiple regression analyses they found that both PROP and QHCL contributed independently to the prediction of sweetness sensation, preference, and intake with effects that were separated from those of sex and adiposity. Individuals who tasted PROP as least bitter and QHCL as most bitter reported the greatest preference for and intake of added sugars. On the basis of these results it is concluded that measures of taste variation showed significant correlation with sweetness sensation and preference, as well as sugar intake. In addition, these results also showed that elevated sweetness preferences are associated with a high intake of added sugars and consumption of sweet food, and vice versa. These findings were in accordance with Holt et al. 2000. In contrast, other studies have failed to show this relationship (Mattes & Mela 1986). According to Drewnowski (1997), the lack of relationship between sweetness preferences and sugar intake might be caused by the fact that individuals restrict their intake of sweet foods due to their knowledge of weight-related and nutritional factors.

THE RELATION BETWEEN PREFERENCE FOR SWEET TASTES, SUGAR INTAKE, AND OBESITY

The rates of obesity in Latin America have been increasing as the region's countries emerge from poverty. Estimation of the prevalence of obesity in the Latin American population varies from 9.9% to 35.7% (Filozof et al. 2001; Bautista et al. 2009). Urban populations and women are the most affected groups (Bautista et al. 2009). In five Latin American countries between 1994 and 1996, the prevalence of obesity in women varied between 1.4-7.6%, while the prevalence of childhood obesity varied between 2.1-12.1%. The prevalence of obesity in Latin America seems to be independent of socioeconomic status and educational level (Uauy, Albala, & Kain 2001). The crucial factors contributing to the rise in obesity seem to be dietary changes and increased in-
activity. Dietary changes include an increased intake of energy-dense food rich in fat and carbohydrates (Bautista et al. 2009; Uauy, Albala, & Kain 2001).

A relevant question in the search for solutions to this epidemic has to be whether sweetness perception and preference for and liking of sweet food can be directly linked to the increased prevalence of obesity in Latin America, since these parameters may be associated with obesity? This relationship has been called the “sweet tooth theory” (Snyder et al. 2006; Drewnowski 1997). The hypothesis was that heightened preference for and intake of sweet foods was directly correlated to obesity (Rodin, Moskowitz, & Bray 1978; Drewnowski 1997). In Latin America, sugar is very readily available since many of its countries produce large quantities of sugar cane (Bjørn & Kidmose 2011).

Few studies have investigated how preferences for sweetness are related to food intake and obesity. Although the evidence is scarce, preferences do seem to relate to obesity – but not necessarily preferences for sweetness. Snyder et al. (2006) showed that liking of sweet foods increased with BMI for the same perceived sweetness. Matsushita et al. (2009) also found a positive association between a preference for sweet tastes and weight increase among women. A study by Sharma and Hedge (2009) compared the food preferences of normal-weight and obese pre-teen children (n=500). They found that 51.1% of overweight and obese children preferred sweet and fatty foods frequently, compared to 24.2% of the normal-weight and under-weight children. Concordantly, 53% of the underweight and normal-weight children preferred not sweet and fatty foods compared to 18.2% of the overweight and obese children.

These results suggest that children who already need to pay attention to their weight like and consume more sweet and fatty foods (which are typically energy-dense and highly palatable) than their leaner counterparts (Sharma & Hedge 2009). Davis et al. (2011) found that preferences for sweet and fatty foods were positively correlated with various eating variables that accounted for the variance in BMI. Sator et al. (2011) investigated differences in sweet taste perception and implicit attitude toward sweetness using an implicit association test (IAT) between normal-weight and overweight/obese adults. The study showed that the obese adults perceived sweet tastes as less intense ( -23%) and reported 2.1 times higher IAT scores for sweetness than normal-weight controls. It was concluded that obese individuals were more implicitly attracted to sweetness than normal-weight individuals. These findings indicate that there are some differences in food preferences between normal-weight and obese subjects, particularly with regards to sweet and fatty foods.
In contrast to the studies that showed a positive relationship between high preference for and consumption of sweet food and obesity, other studies using sucrose solutions, sweetened soft drinks, or chocolate milkshakes found no correlation between sweetness preferences and body weight (Drewnowski 1997). Cox et al. (1999) showed in a human intervention study with obese and lean consumers that there was no difference in liking of foods with different taste qualities between the two groups. Instead, they found that foods classified as “salty/savoury” foods contributed with significantly more energy compared to food classified as “sweet” and that obese subjects derived more energy from foods classified as “salty/savoury”, which were correlated with a diet higher in energy density than the lean subjects.

These results were supported by Drewnowski et al. (1985), who found that obese subjects preferred high-fat stimuli (>34% lipid) that contained less than 5% sucrose, in contrast to normal-weight subjects that optimally preferred stimuli containing 20% lipid and less than 10% sucrose. In a review of Mela (1996), it was concluded that consumption of diets moderate or high in fat or energy density combined with low physical activity as well as several other factors (e.g. genetic predisposition, cognitive restraints) appear to be critical contributors to development of obesity. Furthermore, Mela (1996) also claimed that preferences for and consumption of dietary fat are linked to weight status based on existing literature.

With respect to differences in preference for sweet and fatty food, ethnicity also seems to play a part. In a study of the food preferences of whites and Pima Indians, the Pima Indians rated solutions that vary in sugar and fat content significantly sweeter than whites, and women also rated sweetness higher than men. The Pima Indians liked sweet and creamy solutions less than the white participants did. Moreover, a heightened hedonic response to these solutions among the Pima Indians was associated with weight gain (Salbe et al. 2004).

In summary, it is difficult to conclude whether sweetness perception, liking, and preferences influence sugar intake as well as development of obesity or result in differences in obese subjects compared to lean subjects; the matter remains unresolved. Inconsistent results reported in different studies over many decades combined with the different designs and set-ups of these studies prevent us making any clear and unambiguous conclusions. Sugar intake and obesity are very complex issues, and both are affected by multiple factors, as has been shown in this review.
BIBLIOGRAPHY


