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Sugars or sweeteners: towards guidelines for their use in practice – report from an expert consultation*

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Abstract

With the aim of suggesting recommendations regarding the practical implementation of sweeteners from a nutritional point of view for different groups of consumers, based on present scientific knowledge, the Swedish Nutrition Foundation (SNF) arranged a workshop focusing on the use of sugars and sweeteners in relation to obesity, diabetes, dental health, appetite, reward and addiction. The discussions and conclusions are summarized in this article. It was concluded that restrictions to keep the intake of refined sugars within the recommendations (10E%) should be achieved by limited intake of foods high in sugars, e.g. sweet drinks and candies, rather than other foods that provide less significant amounts of sugars. From a practical point of view it may be useful to restrict the intake of foods high in sugars, especially drinks, to a small amount and to a limited number of occasions, e.g. once or twice a week. Regarding sweeteners, the present intake is considered to be safe from a toxicological point of view. Non-caloric intense sweeteners may be useful for lowering the energy content of liquid and semi-solid foods. Sweeteners may also provide tooth-friendly alternatives within certain food categories, but do not reduce the erosive potential of acidic foods.

Keywords: *appetite; dental health; diabetes; obesity; reward; weight regulation*

Introduction

Sweet taste is one of our favourites from the very first minutes of life. We enjoy sweetness from a range of food products mainly through added sugars and sweeteners. However, sweet taste is also one of the most controversial aspects of people's food habits. During the past few years sugars have fuelled the media debate and they are claimed to be

one of the most important dietary factors behind the obesity epidemic and other health problems. Furthermore, sugar has been described as a drug causing addiction. The scientific evidence for such claims is, however, rarely stated. Nevertheless, the intense debate has raised the consumers' awareness of the sugar content of different food products. As a result the use of sweeteners in foods has increased. However, sweeteners have also always been perceived with scepticism by the media and the general population. Alarming reports connecting sweeteners to many severe diseases such as cancer are still circulating in the media, despite the fact that those allowed in foods have undergone thorough safety evaluations. With the increased number of food products containing sweeteners questions regarding their nutritional relevance for different groups of consumers have also come into focus. At present there are no official recommendations considering the practical implementation of sweeteners.

With this background, and on the initiative from the Swedish food sector, the SNF Swedish Nutrition

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Foundation carried out the project “Sugars and sweeteners – safety and practical implications”. One main objective of the project was to suggest recommendations regarding the practical implementation of sweeteners from a nutritional point of view for different groups of consumers, based on present scientific knowledge. With this aim a workshop was arranged in Stockholm on 8–9 February 2006. Discussions and conclusions from this meeting, focusing on the use of sugars and sweeteners in relation to obesity, diabetes, dental health, appetite, reward and addiction, are summarized here. Some basic facts about sweeteners are briefly summarized in Box 1 and Table 1. Facts and safety aspects of sweeteners will be reviewed in more detail in a forthcoming issue of this journal. Facts about sugars and the present scientific knowledge regarding health effects of sugars are summarized in a separate report (7). A review covering the effects of dietary fructose on lipid metabolism, body weight and glucose tolerance is also published in this issue (8).

Dental health

Dental caries

Dental caries is a disease that appears in all countries and all populations, but varies in scope and degree of severity. Caries may develop if the balance between the attack and the defence factors is disturbed for a long period (9). This can result from behavioural changes, e.g. frequent intake of sugars and low use of fluoride. Currently, nearly half of all children and adolescents in Sweden have

Box 1. Facts about sweeteners

Rules for the use of sweeteners in food products

The safety of sweeteners permitted in the European Union (EU) is evaluated by national authorities and the Scientific Committee for Food (SCF) (1–5).

The use of sweeteners in the EU is regulated by a framework directive (Council Directive 89/107/EEC of 21 December 1988 on the approximation of the laws of the Member States concerning food additives authorized for use in foodstuffs intended for human consumption, as amended by Directive 94/34/EC) and a specific directive (European Parliament and Council Directive 94/35/EC of June 1994 on sweeteners for use in foodstuffs, amended by Directives 96/83/EC and 2003/115/EC). The annexes to the above-mentioned specific Directives provide the information on which sweeteners are permitted in different foodstuffs or groups of foodstuffs together with the maximum usable doses. Information about permitted sweeteners is also available in Danish and Swedish (6).

Table 1. Sweeteners permitted in the European Union (EU)

	E number ^a
Intense sweeteners^b	
Acesulfame kalium	E 950
Aspartame	E 951
Aspartame–acesulfame salt	E 962
Cyclamate: cyclamic acid and its Na and Ca salts	E 952
Neohesperidine DC	E 959
Saccharin and its Na, K and Ca salts	E 954
Sucralose	E 955
Thaumatococin	E 957
Bulk sweeteners^c	
Erythritol	E 968
Isomalt	E 953
Lactitol	E 966
Maltitol and maltitol syrup	E 965
Mannitol	E 421
Sorbitol	E 420
Xylitol	E 967

^a The number under which the substance is registered in EU.

^b Hundreds or thousands of times as sweet as sucrose; non-caloric; no bulking effect. All except for neohesperidine and thaumatococin are artificial sweeteners. Na: sodium, Ca: calcium; K: potassium.

^c Lower or similar sweetness and less energy than sucrose.

no visible signs of caries, which means that they have no fillings or cavities in their teeth. However, a large proportion of them may have initial lesions that can be observed on radiographs. In contrast to children and adolescents who have little or no caries, there is one group with a moderate, and one group with a large number of caries lesions. Families with low socioeconomic and educational levels and immigrant backgrounds are regarded as a high-risk group (10). Dental caries has also been associated with increased body weight in children (11). Caries also occurs frequently in elderly people. This is due to a higher occurrence of diseases and increased medication, together with a larger number of teeth remaining in this age group than had previously been the case.

In 2002 a project group within the Swedish Council on Technology in Health (in Swedish: Statens beredning för medicinsk utvärdering, SBU) conducted a systematic review of the methods for caries prevention to determine the state of knowledge in the field (9). Regarding diet and diet-related factors SBU stated that sugars are important substrates for caries-promoting bacteria. Reducing sugar consumption, especially intake frequency, would help to improve both dental and

general health. However, according to the SBU review the effect of recommendations to reduce sugars in the diet, aimed at preventing caries, was insufficiently assessed. It was also concluded that daily use of toothpaste was the most effective method of preventing caries in the permanent teeth of children and adolescents. Other systematic reviews on caries risk also concluded that the relationship between intake of sugars and caries was much weaker in the modern age of fluoride exposure than it used to be (12, 13). Sweeteners, including sorbitol and xylitol, are not substrates for caries-promoting bacteria, and they may therefore be considered more tooth friendly than sugars. However, according to SBU the evidence was insufficient to determine whether these sweeteners have a preventive effect. Furthermore, they do not lower the erosive potential of acidic foods (see below).

Dental erosion

Dental erosion is another tooth disorder that has been associated with food habits (14). Frequent intake of acidic foods, especially drinks, has been linked to softening of dental hard tissues. However, some beverages appear to be less erosive than others within the same class and it has been shown that the erosive potential cannot be predicted by pH alone, but is also affected by other factors, e.g. the type of acid. Furthermore, extensive erosion is associated with a way of drinking in which the drink is kept in the mouth for a long period. The manner that drinks are introduced into the mouth (e.g. gulping, sipping, use of straw) will also affect the erosive challenge to the teeth. Night-time exposure to erosive agents may be particularly destructive because of the absence of salivary flow.

Diabetes

In the 1980s several studies showed no adverse effects on glycaemic controls, lipids and lipoproteins when diets containing small amounts of sucrose (usually about 50 g day⁻¹) were compared with sucrose-free diets in diabetes (15–17). These studies led to a more liberal approach regarding sucrose restriction as presented in the new evidence-based guidelines from the American Diabetic Association and the European Diabetes and Nutrition Study Group (18, 19). According to these guidelines moderate intake of free sugars may be incorporated within the diet of individuals with diabetes. However, as for the general population the intake of

added sugars should not exceed 10% of the total energy (*E*%). Sucrose and sucrose-containing foods should also be eaten in the context of a healthy diet including carbohydrates from wholegrain cereals, fruits, vegetables and low-fat milk. Furthermore, for diabetes patients the total carbohydrate quantities and the sources and distribution throughout the day should be selected to facilitate near-normal long-term glycaemic control [glycosylated haemoglobin (HbA_{1c}) levels]. In those treated with insulin or oral hypoglycaemic agents timing and dosage of the medication should match the quantity and nature of dietary carbohydrates. Studies in subjects with type 1 diabetes have demonstrated a strong relationship between the premeal insulin dose and the postprandial response to the total carbohydrate content of the meal. For individuals receiving fixed doses of insulin, day-to-day consistency in the amount of carbohydrate is important (18). The total amount of carbohydrate in the food or meal is thus at present considered to be more important than the source or type, but according to the European recommendations low glycaemic index foods are suitable provided that other attributes of the foods, e.g. fat quality and content, are appropriate (19).

Owing to the more liberal approach to sucrose in diabetes the need for non-glycaemic intense sweeteners can be considered to be limited. With regard to the glycaemic effect of various foods it should be stressed that foods containing intense sweeteners may provide a more or less pronounced glycaemic response, depending on their total composition. For example, starch may be used to add volume to foods sweetened with non-bulking intense sweeteners. Starch may increase glycaemia to an even greater extent than isocaloric amounts of sucrose. From this point of view the use of intense sweeteners may therefore be considered relevant mainly in liquid products.

Obesity and body weight control

Overweight and obesity are generally accepted as resulting from an imbalance between food intake and daily physical activity. The urgency of taking public action regarding physical activity is generally accepted, but there is still much debate about dietary factors such as total fat intake, intake of sugars and intake of rapidly digested carbohydrates. Evidence that the regulation of fat balance has lower priority than the regulation of protein, carbohydrate and alcohol balances has contributed

to the general knowledge that fat intake increases the risk of excess energy intake and promotion of fat storage. Only a small reserve of 300–500 g carbohydrates can be stored as glycogen in the human body and any excess must be oxidized or converted to fat by *de novo* lipogenesis. This biochemical pathway for the conversion of carbohydrate to fat exists in humans, but is used mainly under extreme circumstances, when the intake of fat is very low and the intake of carbohydrates exceeds the total need of energy (20). Energy from different nutrients may be considered relatively equal as long as there is energy balance. For sugars there is little evidence for negative effects on body-weight control apart from the energy content. Limited amounts of added sugars in solid foods can be a part of a weight reduction programme (21). Frequent use of carbohydrate-sweetened beverages could, however, promote weight gain since taking sugars in liquid form makes it easy to overconsume energy (22). The risk of weight gain seems considerably increased when frequent use of carbohydrate-sweetened beverages is combined with a sedentary lifestyle.

Intense sweeteners reduce the energy density of liquid products and may be helpful for those who are aiming to lose weight (23–25). However, in solid foods the use of intense sweeteners leads to a reduction of energy content only when dietary fibre, and not starch or fat, is used as a bulking agent instead of sugars. Although the energy content of bulk sweeteners is somewhat less than that of sugars (approximately 10 kJ versus 17 kJ) their sweetness is less or about similar to that of sucrose. Thus, to obtain the same sweetness bulk sweeteners have to be added in amounts comparable to or greater than those of sucrose. These substances therefore do not significantly contribute to a reduced energy content.

Child obesity

Childhood obesity is a long-term risk factor for adult morbidity and social disabilities. Prevention should target different society levels such as families, schools, health professionals, media, government and industry (26, 27). The recent rapid increase in childhood obesity is related to nutritional changes that have occurred in modern society. Soft drinks have, for example, become a natural part of a child's food habits in many countries, including Sweden (28). It has been shown that children who drink soft drinks consume consider-

ably more energy than those who do not (29), and many researchers propose that this increase in energy intake can in part explain the epidemic of obesity in children and adolescence (30–34). Soft drinks with non-caloric sweeteners may be an alternative when the aim is a reduction in energy intake. The effectiveness of exchanging sugars for non-caloric sweeteners has been questioned by some (35, 36), but not by others (37, 38). No treatment studies have focused on changing to calorie-free soft drinks in children, but clinical experience shows that this treatment strategy may be useful (39), and a focus on decreasing carbohydrate-sweetened soft drinks has been shown to be efficient for weight reduction (32). However, there are reasons to promote water as the first choice of drinks for those who aim to lose weight.

Decreased consumption of carbohydrate drinks may also be positive for overall food habits. For example, substitution of carbohydrate-sweetened drinks with water or drinks sweetened with non-caloric sweeteners does not improve the intake of calcium directly, but allows an increased intake of other calcium-rich foods within the energy need.

Pain relief in small children

The pain-relieving effects of sweet solutions administered orally before carrying out painful procedures in newborns are well documented and recommended in both national and international guidelines (40, 41). Sucrose and glucose solutions, in particular, have been found to reduce effectively signs of pain, when given before heel lancing, venepuncture, intramuscular and subcutaneous injections and circumcision. Glucose was also found to be more effective than local anaesthetic lotion in reducing symptoms associated with pain (42). Sweeteners have also been reported to have a pain-relieving effect in the neonatal period. This effect of sweet solutions seems to occur from 2 weeks to between 2 and 4 months of age. There is still no fully accepted explanation for the underlying mechanism of this pain-relieving effect. Some researchers propose a combination of two mechanisms: that the child focuses on the sweet sensation in the mouth and that the sweet solution triggers the endogenous opioid-receptor system. Recently, however, it was discovered that the administration of an opioid antagonist did not decrease the analgesic effect of orally administered glucose given before blood sampling (43). If the sweet solution was given

through a feeding tube directly into the stomach no effect was observed; the solution needs to be in contact with the mouth and/or tongue (44). Furthermore, repeated doses of glucose did not cause tolerance to the pain-relieving effect (45).

Behaviour

Addiction

The possibility of becoming addicted to sugar has been debated intensively in Sweden both in the media and between researchers (46–48). There is some scientific support for a rewarding effect of sucrose, at least in alcoholic people who seem to have an increased liking of sweets (49). It may also be speculated that the preference for a sweet taste is positively related to the consumption of sweet foods, based on the idea that we become used to the taste of foods that we normally eat. The pleasure of eating sweets may also be associated with losing control over one's desires, with a strong feeling of craving, sometimes expressed as an addiction. However, sucrose addiction, as defined by increased consumption, abstinence and loss of control, has so far not been described for humans in the scientific literature. At present all results supporting sucrose addiction are from experimental studies in animals. As long as sucrose addiction is not proven in humans it might be more appropriate to use terms such as dependence or sensitivity, rather than addiction, when describing certain behaviours with regard to sugars and/or sweetness. The term addiction may have negative effects as it may leave some persons with a feeling that they are not able to take control over their food habits. This may provide excuses not to undertake proper measures to lose weight or change to more healthy food habits for other reasons.

Appetite

The regulation of food intake and eating behaviour is a complex process influenced not only by physiological but also by psychological and social factors, as well as environmental factors such as abundance of food and exposure to food cues (50–52). It appears that the physiological regulation mechanisms against overeating are weak, which evidently contributes to a greater demand for conscious food choices and mindful eating behaviour, especially when the aim is weight control. Different motives to eat or not to eat, ambivalence

and conflicts in relation to food and eating tend to arise when the target is to limit one's intake of food in general or sweets. Moreover, food has symbolic, moral and emotional qualities for many individuals and the relation to food and eating reflects different psychological processes (53). In this context sugars and sweeteners are assigned several meanings and functions depending on individual needs, values and expectations.

The appetite regulation for sucrose has been described in experimental animal studies (54) indicating that opioids stimulate an appetite for sucrose and that sucrose releases endogenous opioids. It has been argued that some sweeteners stimulate appetite (55, 56), but most studies do not confirm such an effect (24, 57–60). The causes and consequences of different responses to sweetness in humans are still poorly understood, and more research is needed to understand the effects of sucrose and/or sweetness on appetite regulation.

Recommendations

In the new edition of Nordic Nutrition Recommendations (NNR) from 2004 it is recommended that 50–60E% should be provided by carbohydrates (61). Refined sugars (sucrose, glucose, fructose, starch hydrolysates and other carbohydrates that do not carry essential nutrients) should not exceed 10E%, especially in children and adults with low energy intake ($< 8 \text{ MJ day}^{-1}$), to ensure adequate nutrient density. Furthermore, it is emphasized that restricted consumption of refined sugars in drinks is especially important in the prevention of obesity. Frequent consumption of sugar-rich foods should be avoided to reduce the caries risk. A restriction of the intake of free sugars to 10E% was also recommended by the World Health Organization (WHO) in a technical report published in 2003 (62). In a later global strategy for health one of the goals is a limited intake of sugars, but without any specified upper limit (63).

According to the Swedish dietary survey Riksmaten 1997–98, the average consumption of added sugars at this time was within the recommendations (64). However, the consumption was substantially higher in the youngest age group and among men. According to a recent survey, children aged 4, 8 and 11 years consume on average 13–15E% added sugar (A. Sohlström, personal communication). In adults, approximately 85% of the added sugars consumed comes from food such as sweetened drinks, cookies,

ice-cream and candies (64). The corresponding figure for children is around 70%. Other foods may also contain added sugars, but their contribution to the total intake of added sugars is generally small compared with sweets and drinks, etc.

NNR does not provide any nutrition recommendations for sweeteners, but states that those allowed for use in foods can be regarded as safe alternatives to sugars. The current consumption of sweeteners is also estimated to be within safe limits (65, 66). Further details regarding the safety and intake of sweeteners will be reviewed by Mortensen in a forthcoming issue of this journal.

Conclusions

The recommended limitation of the intake of refined sugars to 10E% given by NNR and WHO (free sugars) is based on science and practical dietary considerations and has not been questioned. According to recent European recommendations, the same limit is also applicable in diabetes.

Restrictions to keep the intake of sugars within the recommendations may be achieved by different measures according to personal preferences. It was concluded that the main focus should be on foods high in sugars, e.g. sweet drinks, candies, ice-cream and cookies, rather than on other foods that provide a less significant amount of sugars. From a practical point of view it may be useful to restrict the intake of foods high in sugars, especially drinks, to a small amount and to a limited number of occasions, e.g. once or twice a week. Such restrictions may be especially effective in reducing the risk of overweight and dental caries in children.

Regarding sweeteners, the present intake is considered safe from a toxicological point of view. Non-caloric intense sweeteners may be useful for lowering the energy content of liquid and semi-solid foods, but generally not in solid foods. Low-energy sweet foods may provide useful alternatives for some groups of consumers under certain circumstances. Drinks with intense sweeteners were concluded to be useful mainly for obese children in a weight-loss programme. Nevertheless, it may be an advantage not to become used to the sweet taste in foods, and the use of intense sweeteners in the diet of small children may therefore be questioned. Sweeteners may also provide tooth-friendly alternatives within certain food categories, but do not reduce the erosive potential of acidic foods.

Both emotional and cognitive processes can be seen as psychological aspects of eating behaviour mediated by physiological functions of the human body. Eating behaviour is a matter of both physiology and psychology. Therefore, it is appropriate to explore how the different dimensions of eating behaviour are connected and affected by various factors. More research is needed to clarify the nutritional role of sweeteners in the diet, especially with regard to appetite regulation and body weight. The effects on body weight control of carbohydrate source and properties, and the form in which carbohydrate is consumed (solid or liquid), also require further research.

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