Sugar and Our Diet

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This report has been commissioned by the New Zealand Sugar Company Limited and has been reviewed by independent nutritionists. First produced in 2001 it was prepared by an independent registered dietitian and reviewed by four of New Zealand's own nutrition experts; Dr John Birkbeck, Adjunct Professor, Massey University, Winsome Parnell, Senior Lecturer in Nutrition, Otago University, Jenny Reid, Dietitian, Nutrition Consultant and Cliff Tasman-Jones, New Zealand Nutrition Foundation, Medical and Scientific Director.

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Introduction

There is no disputing the fact that we all consume sucrose, or as it is better known sugar, in one form or another. Sugar is an integral part of not only our diet but also our culture. However, it is also one of the most misunderstood food components, and many outdated beliefs surround the role of sugar in a healthy diet.

*Sugar is used to describe purified sucrose or table sugar as are the terms refined sugar and added sugar. In contrast "sugars" is conventionally used to describe all of the mono and disaccharides, as a group.

Key issues associated with common misunderstandings about sugar include: understanding current levels of intake and difficulties in measurements, nomenclature and categorisation of sugars, and health outcomes associated with excessive intakes of sugar. Key areas of ongoing debate include the role of sugar in obesity, diabetes and heart disease. Major concerns expressed about excessive use of sugar include its impact on micronutrient intake, total energy intake and dental decay as well as possible effects on the behaviour of children. There is a body of scientific evidence showing that the many ills attributed to sugar are spurious and this report is an overview of current scientific research about sugar and its role in our diet.

Consumed in moderation as part of a healthy and balanced diet sugar poses negligible risks. Simply put, it makes foods taste good and confers many benefits in terms of food production and preservation.

However, as with all nutrients excessive amounts or inappropriate use of sugar in the diet may pose some risks. The key area of risk that has been identified for sugar is dental caries. Caries develop over time through a combination of factors including poor dental hygiene health, frequent snacking and the eating of "fermentable carbohydrates". All acidic foods and carbohydrates can contribute to decay, particularly if they stick to teeth and form plaque. Reducing the intake of sugar is not enough to guard against tooth decay. Good dental health requires a balanced diet, regular dental hygiene and appropriate fluoride intake.

Why is sugar often labelled a 'bad' food?

When sugar was referred to as "Pure white and deadly" in the middle of the 20^{th} Century, it had many ills attributed to it, including the promotion of diabetes and other non-communicable diseases.

Sugary food is often used as a reward or as a means of spoiling or indulging others. These strongly entrenched cultural habits of sugar tend to support the proposition that if it's so nice it must be bad for you. Sugar and sweet foods in a healthy and balanced diet pose little risk and can confer some benefits. However, as the review of research in this paper shows, sugar per se poses no risks to our health. But as mentioned, excessive or inappropriate use combined with other dietary and lifestyle factors, does.

The Role of Sugar in Foods

Advice to avoid foods containing sugar does not take into account the very important role that sugar plays in many of the foods we commonly eat. Sugar is more than a sweetener, it is widely used for a number of important properties desirable in food production. It makes a unique contribution to the way foods look, taste and last on the shelf. Sugar plays the following roles in food production:

- A bulking agent – contributing to the bulk or body of products, as in some baked goods such as meringues
- Used in fermentation – providing food for yeast in breads and buns in order to produce carbon dioxide to raise the dough
- A preservative – helping to reduce and control the growth of bacteria, moulds and yeast as in jams
- A flavour enhancer – enhancing the taste of sour fruits
- An aid to body and viscosity – in liquid and semi-liquid products, as in syrups and sweet sauces
- A unique colour and flavour – on heating, sugar caramelises to produce a desirable colour and flavour (browning)
- A humectant – by maintaining water content, sugar extends the shelf life of foods
- An anticoagulant – on heating, sugar delays the coagulation of protein

Terminology used to describe sugar

Understanding what we mean by sugar or sugars and then comparing similar measurements is one of the main areas of confusion around sugar. The term “sugars” is commonly used to describe the mono and disaccharides. “Sugar” in contrast describes purified sucrose, and also often describes the terms “refined sugar” and “added sugar”.

Definition of the numerous terms used to describe sugar shown below demonstrate how easily similar but quite different measurements can be confused. For example, one research paper may have measured total sugars while another may have measured total added sugar. This makes it difficult to compare intakes from foods to recommended levels and can lead to wrong conclusions and inconsistencies.

According to food legislation, “sugars” are defined as:

(a) hexose monosaccharides and disaccharides, including dextrose, fructose, sucrose and lactose; or
(b) starch hydrolysate; or
(c) glucose syrups, maltodextrin or similar products; or
(d) products derived at a sugar refinery, including brown sugar and molasses; or
(e) icing sugar; or
(f) invert sugar; or
(g) fruit sugar syrup; derived from any source but does not include –
(h) malt or malt extracts; or
(i) sorbitol, mannitol, glycerol, xylitol, polydextrose, isomalt, maltitol, malitol syrup or lactitol.[(1)]

This is important in New Zealand as it is those sugars that are measured and their total amounts shown on the Nutrition Information Panel on food products.

As mentioned above, there are a number of different terms used to describe sugar and when reviewing or interpreting research it is important to be clear on what is actually being measured and how this relates to recommended intakes. The following terminology is commonly used to describe different sugars:[(2)]

Total sugars includes all naturally occurring and added (refined) sugars that are present in food and drinks.

Natural sugars includes those sugars that that are naturally occurring in foods such as fructose in fruits, vegetables and honey, sucrose in fruits and vegetables (there are many other examples).

Refined sugars includes all sugars that are added to foods and drinks either in commercial or domestic food preparation or are eaten as such. Added sugars can come from a variety of sources including corn syrup, molasses, honey or fructose, sucrose and maltose. Some people perceive sugars such as molasses and honey to be nutritionally superior to sucrose, however there are no significant differences and they do not provide vitamins or minerals at significant levels.

Discretionary sugar (which could be considered a subset of refined sugar) include all refined sugars that people choose to add to beverages, breakfast cereals and other foods at the table. This is almost exclusively sucrose.

Free sugars Most recently, a WHO/FAO Independent Expert Report has developed a new definition which is likely to become commonly used and that is free sugars.[3] Free sugars are defined as all mono and disaccharides added by the manufacturer, cook or consumer plus sugar naturally present and sourced from honey, syrups and juices. The report recommends that 55-75% of total energy be made up of total carbohydrates of which 10% of total energy is free sugars. The difficultly in applying this recommendation will be in measuring what are free sugars compared to those that are naturally occurring in food. There is yet to be a method developed to measure them separately.

When looking at sugar intakes of populations we are generally using data that describes the intake of total sugars. However, it is sometimes interpreted as being only the sugar that is added to foods or even sucrose. The reality is that it is quite difficult to distinguish between the two as our food composition data does not differentiate chemically between total and added sugar. Only by having a 100% accurate recipe for a product and any ingredients that may make up the remainder of that product can we know what proportion is natural or added discretionary sugar.

In reality, it is likely to be more accurate and effective to communicate about total sugar content rather than trying to make distinctions that are likely to be arbitrary and unable to be monitored.

The History of Sugar

It is generally accepted that sugar was first harvested for its flavour more than 5,000 years ago when it grew as sugar cane in the Pacific Islands. Through migration, the plant spread and in 510 BC it is recorded that Emperor Darius of Persia invaded India and discovered a "reed which gives honey without bees". The widespread expansion of sugar production around the globe is attributed to the invasion of Persia in 700AD by the Arab peoples who learnt how to harvest sugar cane and established sugar production in the majority of countries that they went on to conquer.

Sugar was only discovered by western Europeans as a result of the Crusaders returning home in the eleventh century and describing a "new spice" which was believed to have considerable medicinal properties. The subsequent centuries saw a major expansion of western European trade with the East including the importation of sugar. At this stage sugar was very much a luxury item with prices recorded at "two shillings a pound" in London in 1319 AD – the equivalent of US$100 per kilo at today's prices.

It was the greater availability and more widespread consumption of sugar, which first led physicians to begin pronouncing it as the cause of various illnesses. In 1606 a French physician, Joseph du Chesne warned that sugar's whiteness hid a dark and dangerous nature, and in 1647 it was even singled out as the cause of the disease we know today as tuberculosis.

Up until the eighteenth Century sugar was only produced from sugar cane. Sugar was first extracted from sugar beet in 1748 by a German scientist, Andreas Marggraf. The first sugar beet factory was established in 1799 in Breslau, Germany.

Sugar is currently produced in over 120 countries and global production exceeds 148.8 million tonnes of raw sugar per year. Seventy percent of sugar is produced from sugar cane with the remainder produced from sugar beet.

Sugar's Natural Process

Sugar is a natural product and the process it undergoes from sugar cane to sugar crystals involves no addition of artificial flavourings, colourings or preservatives.

Sugar cane is grown in tropical countries and most of New Zealand's supply comes from Queensland, Australia. The processing of sugar cane begins in the mill where the cane is crushed. The juice is then filtered and boiled to raw unrefined crystals. Refining removes any further impuities and clarifies the liquid sugar before it is crystallised. A wide range of sugar products are then able to be produced (see Appendix 1 for the different varieties of sugar).

The Nutrition of Sugar

Sugar is a member of the carbohydrate family. For most of the world's population, carbohydrates are an important source of energy. Sugar accounts for around 10-12% of all carbohydrate produced worldwide.[(4)]

Carbohydrates include simple sugars (mono and disaccharides; oligosaccharides) and complex carbohydrates called polysaccharides. Glucose is one of the main units of the sugars.

Carbohydrate is stored as glycogen in the liver and muscle of animals, while in plants it is usually stored in the form of starch. Glycogen and starch are built up of many units of glucose joined to from a long chain on a branching chain by specific linkages (either 1 – 4 or 1 – 6 carbon linkages).

Carbohydrates are classified according to their chemical structure, see Figure 1.

Figure 1

Classification of Carbohydrates According to Structure

Monosaccharides	Glucose, Fructose, Galactose	One sugar unit
Disaccharides	Sucrose, Lactose, Maltose, Isomaltose	Two sugar units
Oligosaccharides	Raffinose, Stachyose, Fructo-oligosaccharides	2-10 sugar units
Polysaccharides	Cellulose, Hemicelluloses, Pectins, B-Glucans, Fructans, Gums, Mucilages, Algal polysaccharides	Many sugar units
Sugar alcohols	Sorbitol, Mannitol, Xylitol, Lactitol, Maltitol	Structure partially resembles sugar, partly alcohol (without ethanol).

The majority of dietary carbohydrates come from plant foods.[(5)] Examples of sources of carbohydrates include:

- Fructose - found in many fruits and in honey.
- Glucose - small amounts are found in some plants
- Sucrose (commonly known as sugar) is found in sweet root vegetables such as beetroot and carrots.
- Maltose - formed from starch during digestion as well as in brewing.
- Lactose - found milk and milk products and is synthesised by the mammary gland.

The energy content of carbohydrate foods is similar to protein foods while fat contains over twice the energy content as shown in Figure 2.[(6)]

Figure 2

Energy Values

Carbohydrates	4 kcal or 17 kJ per gram
Protein	4 kcal or 17 kJ per gram
Fat	9 kcal or 37 kJ per gram
Alcohol	7 kcal or 29 kJ per gram

Digestion of Carbohydrates

Most carbohydrates are ultimately broken down into glucose with small amounts of excess glucose being stored as glycogen in the muscles. In very rare cases, where there is significant excess of carbohydrate or with excessive intake of sucrose or fructose, carbohydrates may be stored as triglycerides (fats) via de novo lipogenesis. In very simple terms carbohydrate is digested through the following process:

In the mouth	Salivary amylase starts the hydrolysis of starch to simple sugars. Chewing of food physically breaks up the food and exposes it to the amylase.
Stomach	Food is temporarily stored in the stomach permitting continuation of amylase digestion. Further mechanical and acid breakdown of the food and controlled release into the small intestine for further digestion and absorption.
Small intestine	Pancreatic amylase breaks starch down to maltose and isomaltose during which some glucose is formed. The brush border of the jejunal villi have disaccharidases which hydrolyse the disaccharides into their monosaccharide constituents. Sucrase converts sucrose to glucose and fructose, maltase converts maltose and isolmaltose to glucose and lactase converts lactose to glucose and glactose. Glucose and galactose are rapidly transported across the wall of the intestine while fructose is more slowly absorbed.
Liver	The absorbed monosaccharides are transported to the liver via the portal blood stream. Glucose may be converted to glycogen for liver and muscle storage or may be converted to fatty acids.

Blood — The absorption of carbohydrates stimulates insulin release from the pancreatic beta cells. Insulin promotes the formation of glycogen and fatty acids. When there is insufficient insulin or decreased ability of cells to utilise insulin, there is a rise in blood glucose levels. This condition is described as diabetes mellitus.

Glycaemic Index

While the classification of carbohydrate foods according to their chemical structure appears logical it was found to be too simplistic as it did not relate to how different types of carbohydrate react in the body – specifically how they were digested and the effect on blood glucose levels.

To compare foods according to their true physiological effect on blood glucose levels the term glycaemic index (GI) was devised.[7]

The GI factor of foods is simply a ranking of foods (0-100) based on their immediate effect on blood sugar levels compared to glucose. A food with a lower GI causes a slower, more gradual rise in blood glucose compared to a food with a higher GI. Low GI is considered to be less than 55, intermediate GI 55 to 70 and high GI greater than 70.

Carbohydrate foods that break down quickly during digestion have the highest GI index. Carbohydrate foods that break down slowly releasing glucose gradually into the blood stream have low GI factors. This classification of carbohydrate foods showed some surprising results. Of particular note was the fact that sugar was found to be a food with a moderate GI factor, not the high GI factor it was expected to have. The reason for this is that sucrose is made up of glucose and fructose which is rapidly metabolised and appears only briefly in the blood stream.

Figure 3 below shows the GI factor of some common foods.

Figure 3

The GI Factor of Common Foods[7]

HIGH GI > 70		INTERMEDIATE GI 55-70		LOW GI < 55	
White Bread, 1 slice	70	Basmati Rice, boiled, 1 cup	58	Medium sliced apple	38
Jelly beans, 5	80	Coca-Cola™, 1 can	63	Baked Beans in Tomato Sauce, ½ cup	48
Mashed potato, ½ cup	91	Croissant, 1	67	Toasted Muesli, ½ cup	43
Medium boiled potato, 1	88	**Sucrose, 1 tsp**	**65**	Skim milk, 1 cup	32
Pretzels, 50g	83	Cheese & Tomato Pizza, 2 slices	60	Peanut M&Ms, 1 50g packet	33
Boiled pumpkin, ½ cup	75	Sultanas, ¼ cup	56	Apple muffin, 1	44
Fruit Roll-up, 1	99	Digestive Biscuits, 2	59	Orange Juice, 1 cup	46
Soda Crackers, 3	74	Weet-Bix, 2	69	Cooked White Spaghetti, 1 cup	41
French Bread, 30g	95	Toast (1 slice)	70	Snickers Bar, 59g	41
Dried Dates, 5	103	Macaroni & Cheese, 220g	64	Banana Cake, 1 slice	47

The most interesting findings from the work on the glycaemic index of foods are what it has taught us about the effects of carbohydrate-containing foods on blood glucose. Prior to the development of the GI and our understanding of the impact of different carbohydrate foods on our blood glucose it was assumed that complex carbohydrates such as rice and potato were slowly digested and absorbed and therefore caused only a small rise in blood sugar. We also assumed that simple sugars by themselves were digested and absorbed quickly, producing a large increase in blood glucose levels. However, the reality is that the foods we eat are usually made up of a combination of carbohydrates and therefore the impact on blood glucose varies considerably depending on food composition, cooking method and even temperature.

While the GI is a useful tool it does have some limitations. Firstly, it should only be used with predominantly carbohydrate-containing foods and not for foods are high in fat and protein. Secondly, individuals who use the GI to manage blood glucose need to be aware that foods which might appear to have the same GI effect could potentially have quite different impacts on blood glucose as the ingredients in the two foods could differ considerably. The GI of a food substance, when taken by itself, can also be modified by; other foods consumed at the same meal, the form in which the food is consumed and whether it is hot or cold. Each individual can have a different response to GI and so while it is a useful tool, GI is only one aspect of appropriate food selection.

Understanding nutrition labelling and sugar content of foods

Lack of understanding about the sugar content of foods can be compounded if consumers misinterpret the information of nutrition panels on foods.

The Australia New Zealand Food Standards Code is the recognised joint food regulations.

This requires that the majority of packaged products display detailed information regarding their nutritional content. One of the mandated nutrients required in the Nutrition Information Panel (NIP) is sugars. It is important to understand that the amount of sugar referred to in the NIP is the total sugar content of that food and not simply added sugar.

The Code aims to provide consumers with detailed information on the products they are purchasing, including carbohydrate and total sugar content of foods. Most packaged products, regardless of whether a nutrition claim is made or not, are required to display a nutrition information panel. A prescribed format for the panel has been set (see Figure 4) and it is mandatory to declare the level of content of the following nutrients:
Energy, Protein, Fat, Saturated Fat, Carbohydrates, Sugars, Sodium.

Figure 4

Prescribed Format for Nutrition Information Panel[8]

Servings per package: (insert number of servings) Serving size: g (or mL or other units as appropriate)		
	Average Quantity per serving	Average Quantity per 100g (or 100 mL)
Fat (total)	g	g
- saturated	g	g
Carbohydrate (total)	g	g
- sugars	g	g
Sodium	mg (mmol)	mg (mmol)
(insert any other nutrient or biologically active substance to be declared)	g, mg, ug (or other units as appropriate)	g, mg, ug (or other units as appropriate)

Information must be offered for both an “Average Quantity per Serving” and “Average Quantity per 100g”. Where a specific nutrition claim is made the content level of the claimed nutrient or biologically active substance must be declared as well. Therefore, a claim relating to sugars or any type of carbohydrate requires the content of the specific carbohydrate mentioned in the claim to be declared.

However, under the Food Standards Code it is down to the discretion of the manufacturers whether or not a “percentage daily intake” column is included within the Nutrition Information Panel. The “percentage of daily intake” information is intended to help consumers understand the relationship between the nutrient content of a product and the recommended level of daily intake of that nutrient.

An important point for consumers to consider when reading a NIP is that this information relates to the total quantity of sugars not just added sugars. A 250g serving of freshly squeezed orange juice will contain 22.8g of sugar, accounting for a reasonable proportion of that person’s daily sugar intake, yet this is sugar from the oranges and not that added to the juice.

Recommended intake of sugar and other carbohydrates

The New Zealand Nutrition Taskforce (1991) recommended that total carbohydrate provide greater than or equal to 50% of total energy intake for the general adult population, and that sucrose and other free sugars should comprise no more than 15% of total energy.[9] The reference values, used by Food Standards Australia New Zealand (FSANZ), of components of our diet are a good example of the recommended composition of a healthy diet in New Zealand and Australia (See Appendix 2).

The FAO/WHO expert committee recommended that a variety of foods should provide the carbohydrate in the diet, not a single or small number of sources. The consultation recommended that a wide range of carbohydrate-containing foods be consumed so that the diet is sufficient in not only essential nutrients but also total energy, especially when carbohydrate intake is high.[4]

The minimum amount of carbohydrate in the human diet that is needed to avoid ketosis is around 50 g/day in adults. Beyond this, additional energy needs are best met by nutrient-dense carbohydrate foods.[4] Ketones are produced when the body uses fat for energy in the absence of carbohydrate. Side-effects of ketosis include dizziness and nausea and can be potentially damaging to the kidneys. There must also be adequate intakes of protein (with essential amino acids) and essential fatty acids from fat.

Clearly some of the carbohydrate we consume will be from sugar, either added or naturally occurring, but the area that creates some debate is what is an appropriate amount of sugar in relation to total energy intake. There is also confusion about actual intakes of sugar making it difficult to determine whether people are consuming more than is ideal. In New Zealand there is no specific recommendation for the amount of sugar we should consume, however our nutrition guidelines state that we should limit the amount of foods containing sugar that we eat.[10]

The National Heart Foundation's nutrition statement on Carbohydrates and Dietary Fibre recommends that we choose a variety of carbohydrate based foods and use only small amounts of highly sweetened foods or drinks.[11]

In Australia, the Nutrition Taskforce of the Better Health Commission developed a specific recommendation for *refined sugar* to be no more than *12%* of total energy intake.[12] This was in line with several overseas health authorities, which recommended as an achievable goal that between 10 and 12% of total energy be derived from *refined sugar*. Such recommendations cannot be monitored, as most food composition data does not differentiate refined sugars from total sugars.

Most recently a joint FAO/WHO Expert Committee on Diet, Nutrition and the Prevention of Chronic Diseases has released a recommendation that Carbohydrates should provide 55-75% of total energy requirements with free sugars being no more than 10% of energy.(3) As noted earlier, the challenge is to be able to accurately measure free sugars as opposed to those that are naturally occurring.

Sugar and foods containing a significant amount of sugar are included in the "eat least" part of the current food pyramid. This is in keeping with overseas recommendations that refined or added sugar contributes 10 to 12% of our total energy intake. 10 to 12% of energy equates to around 1050 kJ (250 kcal) per day for an adult who might consume 8400 kJ (2000 kcal) per day. This could equate to around 15 teaspoons of sugar but the reality is that adults would consume this sugar as part of the wide range of foods eaten during the day.

Actual sugar intake compared to recommendations

The intake total sugars in New Zealand from the 1997 National Nutrition Survey was found to be 114g (131g for males and 99g for females).(13)

Total sugar was described as total available sugars, which was the sum of all mono and disaccharides (e.g. glucose, fructose, sucrose, lactose). The percentage energy from total sugar was 20% (19% for males and 21% for females) for the total population. There are no data on what proportion of the total available sugars is added and naturally occuring sugar as the food composition data does not distinguish between the two. The most predominant sugar contributing to overall sugar intake was sucrose (62g males and 45g females). Those 15 - 25 years of age had the highest intake of both total sugar and sucrose with a lower intake seen thereafter.(13)

Data from the National Nutrition Survey also showed that the greatest source of sucrose was the sugars/sweets group (29%) of total sucrose intake; followed by non-alcoholic beverages (23%).(13)

The 1991 Life in New Zealand survey found that sucrose intake for a male was 36g and a female 27g per day.[14] There appears to be a large increase in sucrose intake between 1989/90 and 1997, however, some of this increase may be due to better recall methodology in the NNS97.

The 1995 National Nutrition Survey in Australia found that total sugars contributed 19.4 % of adult energy intake, remarkably similar to the findings of the New Zealand Nutrition Survey in 1997. The most highly refined sources (jams, sugar, honey, syrups), contributed just under 8%, well below the upper level recommended of 12%.[12]

Internationally there have been some serious errors in estimates of sugar consumption. A review of some of the earlier estimates of sugar intake in countries such as the US, UK and Australia has shown that sugar intake was not as high as had originally been thought.

These overestimates of sugar intake were largely due to the fact that the information used to make these estimates was based on national food availability data. The data has a high margin of error and some of the sugar deemed available for consumption may have gone into brewing.

Surveys by CSIRO in both Victoria and South Australia in the early 1990's concluded that there was a greater proportion of Australians meeting the recommended dietary guidelines and targets for sugar than for fat, fibre and sodium intakes.[15,16]

In the US the daily intake for refined sugar was estimated at 158g per day when using food availability data from 1978 but the figure from the national survey of the US population in the late 1980's showed an average per capita intake of only 53g per day.[17]

A more recent US study looked at food sources of added sweeteners in the US diet.[18] This descriptive study of 15,000 Americans showed that mean intakes of added sweeteners was 82g of carbohydrate per day, accounting for 16% of total energy intake. However, as this figure includes all sweeteners it is difficult to compare it to previous research. The main point to note though is that the researchers concluded that the intake levels for added sweeteners was in excess of the recommended amount for the general US population. A key factor in the increase in intake of sweeteners was the increased consumption of soft drinks in America.

International Trends in Carbohydrate consumption

Trends in consumption indicate a falling carbohydrate intake in developed countries until the last two decades.[4] During that time some increase has been noted at the same time as fat intakes fall. The major sources of carbohydrate are cereals, representing over 50% of all carbohydrate consumed in both developed and developing countries, with sucrose the next major source, followed by root crops, fruits, vegetables, pulses and milk products.

Data on sources of intake of sugars are only available for developed countries. These data show that similar proportions of sugars are derived from cereal products, milk products and beverages, between countries. There is some variation in the proportions derived from fruit and confectionery, with the UK consuming less fruit and higher amounts from confectionery than countries such as the United States and Australia.[4]

Sucrose data obtained from Canada and the US suggest that sucrose intake is declining in North America. As indicated earlier, however, the increased use of high fructose corn syrup (a source of sugars) as a sweetener is not included in US data for sucrose, and therefore, data on total sugars is what is required to gain a clearer picture of the situation. For the UK, where sugars are expressed as all free sugars in the diet (as percent energy), the trend has been in an upward direction in recent years. Again, there are few reliable data for long-term trends.

Clearly more data are needed, since the recent upward trend in the UK in sugars as percent energy may reflect an increased intake, or change in overall nutrient mix. Absolute intake of sugars and intake as a percent energy are similar for the UK and Australia. Australians however, consume considerably more of their sugars as fruit than in the UK, where sweetened baked goods and sugar products contribute more to the diet.

Are artificial (or non-nutritive) sweeteners a useful substitute for sugar?

Artificial sweeteners, intense or non-nutritive sweeteners as they are also known, are used to replace sweeteners such as sucrose and fructose in a wide range of food products but most commonly in drinks. As the name suggests non-nutritive sweeteners offer no energy. As the role of this report is to review the role of sugar in our diet, discussion in this area centres on their technical effectiveness as sugar substitutes.

The six non-nutritive sweeteners approved by the US Food and Drug Administration are saccharin, (on an interim basis pending further study), aspartame, acesulfame potassium (or acesulfame), neotame and sucralose. More details on each of these is in Appendix 3.

D-tagatose is a more recent entrant into the artificial sweetener category. D-tagatose is nearly as sweet as sucrose and has the same bulk of sucrose while contributing almost no energy.

Foods containing artificial sweeteners are often chosen by people who want to lose weight, and therefore use sweeteners to either reduce their total energy intake, or to allow them to consume a greater quantity and variety of foods while maintaining their overall energy intake.

A further benefit, and therefore reason for their use, is that artificial sweeteners have no effect on blood glucose levels, which is one of the reasons people with diabetes often include them in their diet. It is the position of the American Dietetic Association that non-nutritive sweeteners are safe for use by most people within the approved guidelines. As new non-nutritive sweeteners emerge, the safety of these substitutes used alone or in combination with non-nutritive and other nutritive sweeteners and macronutrient substitutes, such as fat replacers, will need to be examined.(2)

Another group of sweeteners also used to provide sweetness but which are lower in energy than sugar is the sugar alcohols group. Though not technically considered artificial sweeteners, sugar alcohols are lower in energy than sugar, providing around half to three quarters the energy of sugar. They include sorbitol, xylitol, lactitol, mannitol and maltitol and are mainly used to sweeten sugar-free confectionery products. The FDA classifies some of these sweeteners as “Generally Recognised As Safe” (GRAS) and others as approved food additives. The sweetness levels of these substances range from about half as sweet as sucrose to about the same sweetness level.

Sugar alcohols or polyols are chemically alcohol but are derived from sugar molecules. The polyols are slowly and incompletely absorbed from the small intestine into the blood and are converted to energy by processes that require little or no insulin. Some of the polyol that is not absorbed into the blood is broken down into fatty acids in the large intestine which can result in a laxative effect in some people, particularly if they consume them regularly or in large amounts. Although they provide an alternative to sugar for people who wish to reduce their total energy intake, people on a reduced energy diet may wish to avoid them as some people report that sugar alcohols act as “trigger foods”, causing cravings for carbohydrates.

Using artificial sweeteners is one of the strategies used in weight management and weight reduction. However, scientific evidence indicates that substituting sugar free products for sugar rich foods in the diet does not always significantly reduce total daily energy intake in normal healthy adults.[19] The real reduction in total energy content is likely to be modest and the satiating power of the food containing them may actually be reduced, leading to the consumption of energy dense foods at a later time.

Holt found similar effects of carbohydrate on appetite suppression.[20] The Satiety Index ranks foods according to the ability of different foods to satisfy hunger. Holt’s research compared the satiety of 38 different foods when volunteers were fed 240kcal portions of each. These initial findings suggest that carbohydrate foods can be more satisfying than high fat foods. In addition, carbohydrate foods were shown to reduce the inclination to nibble after a meal. However, within each food group there are wide variations. While jellybeans were more satisfying than muesli and yoghurt, oranges were almost twice as satisfying as bananas. It appears that a wide range of factors contribute to satiety ratings including the weight of the portion, its chemical composition and in particular, fibre content.

Several dietary intervention trials have shown that when sugar in the diet is replaced by a low energy sweetener in order to achieve a moderate reduction in habitual carbohydrate and energy intake, subjects subsequently increase their food intake and derive a greater proportion of their energy from fat, i.e. the initial energy reduction is not maintained. In some cases this increased eating did not completely compensate for the energy deficit of the reduced sugar diet but significant weight loss did not occur. Therefore, the available experimental data suggest that low energy sugar substitutes could facilitate the consumption of dietary fat if people choose sugar free products to justify the consumption of larger portions of high fat foods or if subsequent food intake increases in general.[19]

Do different groups in the population consume more sugar than others?

Baghurst et al found no significant difference in intake of sugar across different occupational groups.[21] However, women who were not in the workforce were less likely to be high consumers. Marital status also bore no relationship to added sugar intake in women, but men who had never married were more likely to be high users. Women were more likely to be low consumers of sugar with a much higher proportion being within the low decile of use compared to men (see Figure 5 below). Mean intake for men did not vary significantly by age but for men under 30-years-old there were a smaller number of low users. In women, the high consumption group included a higher proportion of younger women.

Figure 5[21]

Decile	% Men in group	% Women in group
1st decile “low users”	33 (up to 4.7 % of Energy)	67 (3.3 % of Energy)
5th and 6th decile	48 (9.4 – 12% Energy)	52 (7.9-10.4% of Energy)
10th decile “high users”	55 (19.3% of Energy)	45 (18.4% of Energy)

Does sugar reduce the micronutrient content of your diet?

While most nutrition experts agree that sugar is an appropriate part of an otherwise healthy diet, there is one remaining concern. This is that a high intake of added sugar within the context of a diet of appropriate energy content might lead to displacement of more nutritious food and thus increase the potential for deficiency of micronutrients i.e. vitamins and minerals and other essential components of the diet.

On the basis of their work Baghurst et al concluded: “Although high consumers of added sugars had diets which were generally lower in quality as measured by micronutrient density, there were some areas in which the diet appeared to be better.”[21]

Higher sugar intake relative to total energy was associated with lower intakes of a range of micronutrients but in many cases, using the standard of 70% of RDI or less, this did not appear to pose a major problem as intakes were in most cases still well above recommended levels. The main exception was for folate, which is one of the micronutrients most at risk across the population. Vitamin A also showed an increase in risk with increasing relative added sugars intake but again the level of risk was small. Zinc, calcium and magnesium, showed no consistent pattern across the deciles of sugar intake.

Areas in which the diet was better in quality were interesting. In particular, alcohol consumption was much lower in the high added sugar consumers and it appears that substitution of aerated or soft drinks for alcoholic drinks plays a substantial role in accounting for the increased added sugar consumption of this group. Lower relative fat consumption was also apparent although the ratio of polyunsaturated to saturated fat was less desirable among high sugar users.[21]

The results of the Australian study are supported by a more recent US study of Added Sugar and Diet Quality.[22] This study of 16,000 people was conducted by the US Department of Agriculture. The researchers conclude that their data challenges the theory that added sugars displace servings of major food groups or key micronutrients such as Vitamin C, iron, and folate. They say; “The results show added sugars have little or no association with the diet quality of people over the age of 2 years, children or adolescents.”

In addition, a review of data from intake surveys from both the US and the European Union showed no consistent or nutritionally meaningful variation in micronutrient intake across the range of sugar intakes. The U shaped association between sugar intake and nutrient adequacy of the diet suggests that extreme intakes of sugar are not optimal. However, adequate nutrient intakes are associated with a wide range of sugar intakes and those consuming low amounts of sugar tend to consume more energy from fat.[2]

A study of US men of different ages consuming widely differing amounts of sugar (less than 26g, up to more than 60g/100 kcal/day) found only fibre intake was reduced slightly in high sugar diets. In fact, high sugar consumers were more likely to reach at least two thirds of their recommended daily allowance for essential vitamins and minerals than the low sugar consumers. Fat intake was shown to significantly decrease in the higher intake group. The supposition that sugar automatically replaces foods rich in micronutrients, adversely altering micronutrient intake is therefore without foundation.[4] Although this study was only in males, therefore there is a need for additional research looking at female intakes.

Sugar and health: what role does sugar play in the development of lifestyle diseases?

There is a great deal of misunderstanding about the role of individual foods and nutrients in the development of lifestyle diseases and indeed the protection of health. This is partly due to the myths, sometimes promoted by self-appointed experts, whose theories on the influence of foods on health are often based on selective evidence. In some cases the quality of the research used to make these claims is questionable.

Because sugar is an essential ingredient in many foods and is present in some foods that are also high in fat and therefore energy, it can be unfairly labelled as a bad food.

An Australian survey of over 1800 people showed that there was no difference across the deciles in the percentage of people reporting that they suffered from high blood pressure, heart disease, cancer or arthritis in the last 12 months. Nor was there any difference in the amount of exercise they claimed to get either at home, in leisure time or the workplace.(21)

Influence of sugar on food intake and body weight

People who are attempting to reduce their body weight frequently reduce sugar intake as a means of reducing total energy intake. There is no evidence that this is necessary if sugar intake is not excessive. However, some research suggests this may be a false economy and that including small amounts of sugar in an eating plan that has an overall reduction in energy may have significant psychological benefits.

Food intake is regulated by the complex interaction of psychological and physiological events associated with ingestion. When reducing total energy, and therefore food intake, the inclusion of sweet foods can significantly increase satiety and therefore the likelihood of an individual maintaining an eating plan that reduces energy intake.

The hypothesis that sugar plays a role in the development of obesity is a subject of debate. In its position paper(2) on the use of nutritive and non-nutritive sweeteners, the American Dietetic Association argues the following: Sugars suppress the appetite to the same extent as other carbohydrates,(23) there is no relationship between the per-capita amount of sugar available in the food supply and incidence of obesity in the population,(24) and lastly, that epidemiological studies show a direct relationship between obesity and fat intake.(25)

Intake of sweet foods or drinks is limited by changes in the hedonic response to sweetness during consumption. Thus, to a hungry individual a sweet food will be rated as extremely pleasant in taste, but as consumption proceeds, this rating of pleasantness declines. Ratings of foods with different tastes, for example, salty foods, will be unaffected by consumption of sweet foods. This “sensory-specific satiety” limits consumption of one type of food and helps to ensure that a variety of foods are consumed.(26)

Many people believe that sugar and other carbohydrates contribute to overeating and obesity. Despite this popular belief, there is little direct evidence that obese individuals eat excessive quantities of sweet foods. Indeed, a number of cross-sectional surveys on nutrient intakes in developed countries have demonstrated an inverse relationship between intake of fat and carbohydrate.(27) It has been found that obese women prefer sweet-fat combinations while obese men prefer salt-fat tastes. In both instances fat is the common factor in their food preferences.(28)

Preference for carbohydrates was not a standard feature of obesity. Rather, preferences for major food sources of fat as opposed to carbohydrate may be a primary characteristic of human obesity syndromes.(28) Thus, although there is little evidence that any of the various sugars are associated with obesity, sugars are often associated with a high-fat content in foods and serve to increase the palatability of fat.

Obesity

The frequency of obesity has increased dramatically in recent years in most developed and in some developing countries.(29) This is of public health importance because of the clearly defined negative effect of obesity, especially when centrally distributed, in relation to diabetes, coronary heart disease and other chronic diseases. Genetic and environmental factors play a role in determining the propensity for obesity in populations and individuals. Lack of physical activity is believed to contribute to the increasing rates of obesity observed in many countries and may be a factor in whether an individual who is at risk will become overweight or obese.

Given that obesity is due to energy intake in excess of energy requirements, energy containing foods and nutrients have the potential to contribute to obesity.(3)

A joint WHO/FAO expert consultation looked at the strength of evidence on factors that promote or protect against weight gain and obesity.(3) The report concluded that there is evidence that a high intake of energy dense foods promotes weight gain. They define energy dense foods as being: “those foods that tend to be high in fat (e.g. butter, oil, and fried foods), sugar or starch, while energy dilute foods have a high water content.”

While sugar per se is not a direct cause of obesity, high consumption of energy dense foods including those high in fat or sugar are believed to promote weight gain. Of note is the use of the words “high consumption” supporting the general recommendation that a moderate amount of sugar in the diet poses no risk.

The form in which foods are consumed is also discussed within the WHO/FAO report and it may be this is more influential than the specific nutrient source. The report states that a high intake of sugar-sweetened beverages is a probable factor in increasing the risk of obesity. To quote, “The physiological effects of energy intake on satiation and satiety appear to be quite different for energy in solid foods as opposed to energy in liquids. Possibly because of reduced gastric distension and faster transit times, the energy contained in the fluids is less well detected by the body and subsequent food intake is poorly adjusted to account for energy taken in through beverages.”[3]

Research by Ludwig specifically examined the relation between consumption of sugar-sweetened drinks and childhood obesity.[30] However, despite this research often being cited as proof of a direct relationship between sugary drinks and obesity the issue is more complex and this is recognised by Ludwig. He states, “There is no clear evidence that consumption of sugar per se affects food intake in a unique manner or causes obesity.”

Obesity is a major public health issue that requires multifaceted solutions. Appropriate food and nutrition intake is an important part of these solutions. Sugar is an integral part of our diet and the foods that we eat on a day to day basis. It also offers many food benefits such as taste and texture. Sugar is a valuable energy source and therefore its intake needs to be considered in the context of the overall diet. Based on recommendations from nutrition experts it is appropriate for around 10-12% of our energy to be provided by sugars. However, excessive intakes, as with any energy-containing food or nutrient, will increase the risk of nutrient imbalances or energy intake being greater than output, thereby leading to weight gain.

Physical Activity

The total carbohydrate intake requirements of an athlete or sports person with increased energy needs will also increase. In addition, the composition of this carbohydrate intake will need to change to reflect the activity patterns of the individual and their sheer ability to consume the amount of carbohydrate foods they need to meet their total energy needs. Sugars have an important role to play in the diet of athletes and sports people. Sugars are a relatively concentrated energy source so will add energy to the diet without bulk and are also a more rapidly absorbed source of energy which can be important to replenish blood glucose and muscle glycogen stores following an event.(31)

The report of the 1997 FAO expert meeting on Carbohydrates stated the following about the role of carbohydrate and sugar in the diet of athletes:

"There is substantial evidence that supplemental carbohydrate can improve performance for the elite endurance-trained athlete. A high carbohydrate diet during a few days preceding an endurance event, carbohydrate loading, a high carbohydrate pre-event meal and carbohydrate supplementation in the form of carbohydrate-containing beverages have all been shown to enhance performance during long-distance cycling and running. There is however, no evidence that such carbohydrate supplementation would improve performance for the majority of people who engage in recreational physical activity of lower intensity and duration. On the other hand, carbohydrate intake following exercise can help to quickly replenish depleted glycogen stores."(4)

Carbohydrate and Behaviour

It has been suggested that food intake could have important effects on behaviour, particularly in children. Providing breakfast to children who do not typically eat breakfast can increase cognitive performance, but it is less clear that the overall composition of the diet can affect behaviour.[(4)]

One of the major claims against sugar is the assumption that it causes hyperactivity in children. This hypothesis was widely supported by experts and parents alike in the seventies when the Feingold Diet was first mooted. Although it still remains a belief of many, an extensive review of the literature in this area concluded that there is no evidence to support the claim that refined sugar intake has any significant influence on either behaviour or cognitive performance in children.[(32)]

The position paper by the American Dietetic Association states that some research supports the hypothesis that people with negative mood states (e.g. seasonal affective disorders and alcohol withdrawal) should consume carbohydrate rich foods, including sweets, as a way of alleviating their condition. The mechanism by which carbohydrate, including sugars may affect mood is uncertain but may involve the synthesis and release of serotonin in the brain.[(33)] Serotonin controls functions such as temperature regulation, sensory perception, and onset of sleep and appetite.

Diabetes

Until the last few decades sugar was assumed to be the cause of diabetes – mainly because diabetes is a disorder of blood sugar and the sugar we consumed was thought to be directly linked to this.

High and excessive intakes of sugar may contribute to insulin insensitivity and also increases in blood lipids. This is discussed by Barber[(34)] who cites the work of Daly, Vale, Walker, Alberti and Mathers,[(35)] who reviewed human and animal studies into this issue. The conclusions made by the authors were as follows:

- If sucrose intake has an effect on insulin sensitivity it appears to be in diets with excessive intakes of sucrose. There are also more recent data which suggest problems with insulin resistant individuals at lower but still excessive levels.

- Fructose, not sucrose, may in fact be the cause, therefore further investigation is needed. People with hypertriglyceridemia and hyperinsulinaemia or both, may be more susceptible to the adverse effects of high fructose or sucrose intakes. This research could have important implications as high fructose corn syrup is increasingly used as a sweetener in a range of foods, particularly in America.

For people with diabetes, current dietary advice is that moderate amounts of sugar can be included in the daily eating plan as part of a mixed, balanced and healthy diet.[(36)]

Dental caries

While the risk of dental caries increases with intake of sugars, this risk does not work independently from factors such as oral hygiene and fluoridation. Tooth decay begins when bacteria create acid in the plaque that forms on teeth. These acids dissolve tooth enamel. The plaque bacteria can produce acid from any food or drink that contains carbohydrates. The bacterial acid that is produced each time food is eaten also causes calcium and phosphate to be dissolved out of the tooth enamel. If this occurs often, such as more than about six times a day over many months, the enamel crystals will finally break down and a hole in the enamel will form.[(37)]

While carbohydrate foods, including sugary foods play a role in the development of dental caries, the incidence of dental caries is influenced by a number of factors. Foods containing sugars or starch may be easily broken down by amylase and bacteria in the mouth and can produce acid, which increases the risk of caries. Starches with a high glycaemic index produce more pronounced changes in plaque pH than low glycaemic index starch, especially when combined with sugars.[(4)]

In addition, Williams[(38)] refers to the FAO/WHO expert consultation on carbohydrates which says that the incidence of dental caries is influenced by many factors. These include the type of food, frequency of consumption, degree of oral hygiene performed, availability of fluoride, salivary function, and genetic factors.[(4)] Prevention programmes to control and eliminate dental caries should focus on fluoridation and adequate oral hygiene, and not on sucrose intake alone.

The continued dissolving of tooth enamel can be stopped if there is sufficient time between eating or drinking, as enamel crystals can be re-hardened by calcium and phosphate in saliva. Allowing adequate time between meals for teeth to re-mineralise is therefore an important strategy to reduce the risk of tooth decay.[37]

High Blood Lipids (hyperlipidaemia)

Usual intakes of sucrose or fructose do not elevate plasma triglycerides in most persons, including those with diabetes, provided that energy balance is unchanged.[39] However, very high intakes of dietary fructose and sucrose (approx. 2-3 times typical consumption) can result in the elevation of plasma triglycerides.[40]

Conclusions

Sugar has been part of the human diet for thousands of years. Throughout the years it has been an important source of energy, satisfied a desire for sweetness, enhanced the palatability of important foods, facilitated food preservation and manufacture of a wide range of food products.

Over-consumption of sugar may be one factor among others in the development of obesity.   Sugar is also clearly seen as one factor in the development of dental caries, however, good dental hygiene and minimising grazing on foods, especially sugary foods, can help prevent the development of dental caries while still including sugar in the diet.

Nutrition advice and recommendations should focus on the total composition of a person's diet to ensure an appropriate energy balance and nutrient intake. This is achieved by recommending a wide variety of food choices and regular physical activity rather than emphasising restriction of one or two foods. In educating people about the inclusion of sugar in their overall diet the following provide a useful framework:

- Sugar is a source of energy, has taste appeal and enhances enjoyment of other foods, including those providing essential nutrients. It also has important properties which facilitate the manufacture and preservation of some foods.

- Some sugar as part of a healthy diet does not play a major role in the development of diseases such as cancer, heart disease, diabetes or obesity.

- The palatability of foods we need to eat more of, such as fruits, breads and wholegrain cereals can be improved when combined with some sugar. In turn, this may increase the likelihood of these important foods being consumed.

- People should consume a range of drinks using water as the primary means to quench thirst while limiting intake of sweet drinks.

- Strategies to reduce the risk of tooth decay include: maintaining good oral health with regular dental checks, using a fluoridated toothpaste and consuming carbohydrate foods including sugar-containing foods with meals rather than continuously throughout the day.

APPENDIX 1

DIFFERENT VARIETIES OF CANE SUGAR

Information sourced from New Zealand Sugar Company Limited.

White Granulated Sugar – most commonly used sugar with uniform sized crystals.

Caster Sugar – fine white sugar crystals used when a smooth finished texture is required or where sugar needs to dissolve easily.

Icing Sugar – fine white sugar that has been ground in a mill. To prevent caking and improve storage life a small amount of starch is added.

Raw Sugar - natural granulated sugar produced by dissolving, filtering and recrystallising the raw sugar received from the sugar mill.

Demerara Sugar – sugar crystals with a thin layer of molasses giving a golden brown appearance.

Soft Brown Sugar – sugar with a very fine crystalline structure and soft texture produced directly from the dark syrups obtained during the refining process.

Dark Cane Sugar is a moist, dark brown sugar, it's distinctive rich caramel flavour and dark colour coming from natural molasses syrup.

Coffee Crystals – sucrose crystals grown for a long period of time to form larger crystals. By not spraying the crystals with water during the spinning process a thin syrup coating is left on the crystals ensuring a golden brown appearance.

Golden Syrup – made from sugar syrups that have a high mineral and colour content. Sucrose in the syrup is semi-converted to glucose and fructose by the addition of enzymes. Decolourising the syrup by passing it through carbon produces the rich golden colour and distinctive flavor.

Treacle - produced in the same manner as golden syrup with the decolourising stage removed, producing a darker colour and a stronger and slightly bitter flavour.

Organic Sugar – is certified as organic by New Zealand certification authorities. It is a pale brown coloured raw sugar, suitable for a wide range of food and beverage applications.

APPENDIX 2

Reference Values for an Interpretative Element – Percentage of Daily Intake (%DI)

From: FSANZ. Users Guide - Nutrition Information Labelling, July 2002

Food component	Reference value	Basis for reference values	Source of health recommendations for reference amount
Energy	8700 kJ (2100 kcal)	Based on the average energy consumption/day for adults and children over 4 years of age in Australia and New Zealand	1995 National Nutrition Survey, Australia[i] 1991 Life in NZ Survey[ii]
Protein	50g	Protein based on average for RDI for men (55g) and non-pregnant, non-lactating women (45g)	Australian RDI, as per NHMRC 1991[iii]
Fat	70g	Fat based on 30 percent of energy	CDHSH 1994[iv]
Saturated Fat – total	24g	Saturated fat based on 10 percent of energy	CDHSH 1994[iv]
Carbohydrate – total	310g	Carbohydrate based on difference and cross-referenced with survey data and international targets (60 percent of energy)	No RDI or targets set. US value for labelling set at 60 percent of energy
Sugars	62g	Sugars based on 12 percent of energy	Better health Commission Target, Commonwealth Dept Health, 1987[v]
Dietary Fibre	30g/day	Dietary fibre based on 30g per day	Better Health Commission Target, Commonwealth Dept Health, 1987[v]
Sodium	2300mg/day		Australian RDI, as per NHMRC 1991[iii]

i Australian Bureau of Statistics. National Nutrition Survey: Selected Highlights, Australia 1995. Australian Bureau of Statistics, Canberra, 1998.
ii Horwath C, Parnell W, Birkbeck J, Eilson N, Russell D and Herbison P. Life in New Zealand Survey Commission Report: Volume VI: Nutrition. University of Otago, Dunedin, 1991
iii National Health and Medical Research Council. Recommended dietary intakes for use in Australia. AGPS Canberra, 1991.
iv Commonwealth Department of Human Services and Health. Better health outcomes for Australians. National goals, targets and strategies for better health outcomes into the next century Commonwealth Department of Human Services and Health, Canberra, 1994.
v Commonwealth Department of Health. Towards better nutrition for Australians. Report of the Nutrition taskforce of the Better Health Commission. AGPS Canberra, 1987

APPENDIX 3

NON-NUTRITIVE SWEETENERS

From - American Dietetic Association. Position of The American Dietetic Association: Use of Nutritive and Non-nutritive Sweeteners. *Journal of The American Dietetic Association. 1998;98: 580-587.*

The United States leads the world in consumption of high-intensity sweeteners, consuming approximately 50% of the world demand. High-intensity sweeteners can offer consumers a way to enjoy the taste of sweetness with little or no energy intake or glycaemic response. Non-nutritive sweeteners may assist in weight management, control of blood glucose, and prevention of dental caries. The food industry evaluates these sweeteners for many attributes, including sensory qualities (eg, clean sweet taste, no bitterness, odorless), safety, compatibility with other food ingredients, and stability in different food environments. The trend in the food industry is to blend high-intensity sweeteners. Blending can cause sweetness synergy (ie, the combination is sweeter than the individual components), which can decrease the amount of sweetener needed and can improve the overall sweet taste.

FDA has approved 4 non-nutritive sweeteners and regulates them as food additives: saccharin (on an interim basis pending additional study), aspartame, acesulfame potassium (or acesulfame-K), and sucralose

Saccharin

Saccharin exceeds the sweetness of sugar 200 to 700 times. It provides no energy, as it is not metabolized by human beings, and it is not carinogenic. The FDA Center for Food Safety and Applied Nutrition estimates the daily use of saccharin at 50 mg per person per day. The JECFA has set the ADI for saccharin at 5 mg/kg body weight per day. Despite the decline in use, saccharin is the largest-volume, lowest-cost high-intensity sweetener used in the world (nearly 62 million lb were used in *1995).* It is approved for use in more than 100 countries.

Saccharin was originally included on the GRAS listing. In 1977, FDA placed a ban on use of saccharin because it was reported to be a carcinogen in rats.

In the same year, Congress, through the Saccharin Study and Labelling Act, imposed an 18- month moratorium on the FDA ban and required products containing saccharin to bear the following warning: “Use of this product may be hazardous to your health. This product contains saccharin which has been determined to cause cancer in laboratory animals.” Congress has extended this moratorium 7 times, the last to continue through May 2002. In 1991, FDA formally withdrew the proposed ban and considers saccharin to be a food additive on an interim basis for use in cosmetics, pharmaceuticals, foods and beverages, tabletop sugar substitutes, and chewing gum. The amount of saccharin must appear on the food label and is limited to no more than 12 mg/oz in beverages, 20 mg per sweetening equivalent of 1 tsp sugar, or no more than 30 mg per food serving.

Since 1981, saccharin has been listed as an “anticipated” human carcinogen. Studies of high users (ie, persons with diabetes) do not support an association between saccharin and cancer. However, subgroups of persons (eg, male heavy smokers) may present increased risk. The advisory board for the National Toxicology Program did not recommend removal of saccharin from the *Report on Carcinogens,* Ninth Edition (report in preparation).

Aspartame

Aspartame a dipeptide (methyl ester of l-aspartic acid and l-phenylalanine) is 160 to 220 times sweeter than sucrose. Intestinal esterases hydrolyze aspartame to aspartic acid, methanol, and phenylalanine. The amino acids are metabolized to provide 4 kcal/g. Thus, this sweetener does provide energy; however, because of the intense sweetness of aspartame, the amount of energy derived from it is negligible.

In 1981, FDA approved aspartame as a sweetener for a number of dry uses (eg, tabletop sweetener, cold breakfast cereal, gelatins, puddings) and in chewing gum and carbonated beverages. In 1985, the Council on Scientific Affairs of The American Medical Association concluded that “Available evidence suggests that consumption of aspartame by normal humans is safe and is not associated with serious adverse health effects’. FDA has evaluated aspartame use in food and beverages 26 times since its original approval. In 1996, FDA approved aspartame as a general-purpose sweetener for use in all foods and beverages. Aspartame is also approved for use in more than 100 nations.

Demand for aspartame in the United States rose from 8.4 million lb in 1986 to 17.5 million lb in 1992, a figure that represents more than 80% of the world demand. Although soft drinks account for more than 70% of aspartame consumption, this sweetener is added to more than 6,000 foods, personal care products, and pharmaceuticals. Aspartame is available in liquid, granular, encapsulated, and powder forms to extend its use in food and beverage products. The encapsulated form has made aspartame more heat stable and has extended its use in some commercially baked products.

Detailed studies have been conducted to determine how ingestion influences plasma levels of aspartic acid, phenylalanine, and methanol (or the byproduct formate). In studies of healthy adults, a bolus load (up to 200 mg/kg) did not alter levels of plasma aspartate concentrations or blood levels of formate. Plasma phenylalanine response to aspartame varies genetically. Persons with phenylketonuria, a homozygous recessive inborn error of metabolism, are unable to metabolize phenylalanine. In persons with this rare (frequency is approximately 1 in 10,000 whites) inborn error, excess intake of this amino acid causes higher plasma levels and altered synthesis of monoamine neurotransmitters and adverse effects. Thus, medical nutrition therapy for phenylketonuria involves the control of dietary sources of phenylalanine, including aspartame. Foods containing aspartame must, by FDA requirements, contain a label indicating that they contain phenylalanine.

Persons with phenylketonuria appear to tolerate the amount of phenylalanine in diet soda sweetened with aspartame (approximately 104 mg/12 oz). Heterozygotes for phenylketonuria do not show changes in cognitive performance or in electroencephalograms after 12 weeks of consuming either 15 or 45 mg/kg aspartame per day. In persons without phenylketonuria, single bolus studies of aspartame (up to 50 mg/kg body weight) or repeat dose studies show a plasma phenylalanine response near the normal postprandial range and considerably lower than that observed in persons with phenylketonuria or those with mild hyperphenylalanemia.

Aspartame breaks down to diketopiperazine in liquid systems with heat exposure and loses it sweetness. Animal toxicity studies show that even if all aspartame was converted to diketopiperazine in beverages, the amount would be well below the ADI of 3,000 mg/kg for diketopiperazine.

Some persons report allergic reactions to aspartame, including edema of the lips, tongue, and throat; dermatologic reactions; and respiratory problems. However, 2 double- blind challenge studies report difficulty recruiting persons who claim an allergic response to aspartame and failure to reproduce the allergic reaction in controlled experiment conditions.

FDA increased ADI for aspartame to its current level of 50 mg/kg body weight when it was approved for use in carbonated beverages. Post market assessment of aspartame shows that estimated daily intake of aspartame is below this ADI (39): aspartame eaters (at least 90th percentile of consumption) in the general population consume 6% of the ADI (3.0 mg/kg per day) and those aged 1 to 5 years consume 10.4% of the ADI (5.2 mg/kg per day). Food labels can help consumers identify foods and beverages that contain aspartame, although the amount is not generally labeled. Consumers would need to contact the companies to determine the amount of aspartame in each product. Nonetheless, the amount in some common foods is: up to 225 mg in a l2-oz diet soda, 100 mg in an 8-oz drink made from powder, 80 mg in an 8-oz yogurt or a 4-oz gelatin dessert, up to 32 mg in 3/4 c sweetened cereal, and up to 47 mg in 1/2 c frozen dairy dessert. As a tabletop sweetener, packets contain 37 mg aspartame and are equivalent to the sweetness of 2 tsp sugar. In the granular form, 1 tsp contains 16 mg aspartame and equals the sweetening of 1 tsp sugar. To reach the ADI, an 18 kg (nearly 40 lb) child would need to consume 900 mg aspartame per day, which translates to 24 packets of sweetener (equivalent to 48 tsp sugar), four 12-oz cans of diet soda, or nine 8-oz glasses of fruit drink made from a powder.

Acesulfame-K

Acesulfame-K (5,6-dimethyl- 1 ,2,3-oxathiazine-4(3H)-one-2,2-dioxide) is approximately 200 times sweeter than sucrose. The “K” refers to potassium. Acesulfame-K can withstand high cooking/baking temperatures. Blends of acesulfame-K with other nutritive and nonnutritive sweeteners can synergize the sweetness potential and decrease the bitter taste. This sweetener does not provide any energy; it is not metabolized by the body and is excreted in the urine unchanged.

This sweetener was evaluated for safety by JECFA in 1983 (40,41). FDA approved acesulfame-K in 1988. Both regulatory groups have set an ADI of 15 mg/kg body weight. In the United States, acesulfame-K is approved for use as a tabletop sweetener and as an additive in chewing gum, confections, desserts, yogurt, sauces, and alcoholic beverages. FDA is reviewing acesulfame-K for use in nonalcoholic beverages. The tabletop sweetener contains approximately 0.4 g acesulfame-K per packet. The amount of acesulfame-K added to food products is very small because of its intense sweetening power and because it is often used in combination with other sweeteners.

Sucralose

Sucralose (trichlorogalactosucrose) is 600 times sweeter than sucrose. Sucralose provides no energy; it is not well absorbed and is excreted in the urine essentially unchanged. This sweetener is heat stable in cooking and baking.

Sucralose was approved in April 1998 as a tabletop sweetener and for use in a number of desserts, confections, and nonalcoholic beverages. FDA concluded from a review of more than 110 studies in human beings and animals that this sweetener did not pose carcinogenic, reproductive, or neurologic risk to human beings. In 1990, JECFA increased the temporary ADI from 0 to 3.5 mg/kg body weight to 0 to 15 mg/kg body weight (referenced in the original).

Neotame

Neotame was approved by the US Food and Drug Administration in July 2002 as a general –purpose sweetener in a wide variety of food products, other than meat and poultry.

Neotame is a non-nutritive, high intensity sweetener manufactured by the NutraSweet Company of Mount Prospect Illinois.

Depending on its food application neotame is approximately 7,000 to 13,000 times sweeter than sugar. It is a free-flowing, water soluble, white crystalline powder that is heat stable and can be sued as a tabletop sweetener as well as in cooking applications. Examples for uses which neotame has been approved include baked goods, non-alcoholic beverages (including soft drinks), chewing gum, confections and frostings, frozen desserts, gelatins and puddings, jams and jellies, processed fruits and fruits juices, toppings and syrups.

In determining the safety of neotame, FDA reviewed data from more than 113 animal and human studies. The safety studies were designed to identify possible toxic effects, such as cancer-causing, reproductive, and neurological effects. From its evaluation of the neotame database, the FDA was able to conclude that neotame is safe for human consumption..

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GLOSSARY

Glycogen The storage form of carbohydrate in animals made up of chains of glucose.

Glycaemic Index A ranking of foods based on their immediate effect on blood sugar levels.

Humectant Food additives used to keep moisture in foods, such as in spreads.

Insulin A hormone secreted by the pancreas whenever the level of glucose in the blood rises. Insulin allows the glucose to pass from the blood to the cells and muscles.

Invert sugar A sugar which has been broken down to its component parts of glucose and fructose by a combination of the sugar with an acid. It is sweeter than sucrose.

Ketones Substances formed when the body uses fats for energy in the absence of carbohydrates. Ketones are toxic substances with moderate to severe side effects.

Lipogenesis The process of digestion and breakdown of lipids in the body.

Nutrition claim A claim on a food product relating to the nutrient content or nutritional characteristics of the product.

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