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THE DIRECTOR GENERAL

OPINION

of the French Food Safety Agency on the types of carbohydrates to be introduced in the monitoring plan for carbohydrate compositions and intakes

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Context of the request

On 26 April 2006, the French Food Safety Agency (AFSSA) received a letter dated 24 April 2006 from the Directorate General for Food (DGAL), the Directorate General for Health (DGS) and the Directorate General for Competition, Consumer Affairs and Fraud Control (DGCCRF) requesting scientific and technical support (STS) on the types of carbohydrates to be introduced in the monitoring plan for carbohydrate compositions and intakes.

Background of the request

There are currently three main nutritional recommendations relating to carbohydrates. These are to:

- increase consumption of foods that are a source of complex carbohydrates;
- reduce consumption of simple carbohydrates;
- increase consumption of fibres.

These recommendations are consistent with the objectives of the National Nutrition and Health Programme (PNNS) and have also been expressed by AFSSA (AFSSA 2004 a).
Furthermore, AFSSA recommends that both qualitative and quantitative studies be undertaken to monitor carbohydrate content in commonly consumed foods (AFSSA 2004 a).

In this context, a working group on carbohydrates was set up by the DGAL. As part of this working group, AFSSA proposed to implement a study to examine changes in the population's quantitative and qualitative carbohydrate intakes, and changes in the carbohydrate composition of products, particularly relating to simple carbohydrates that are "added" during manufacturing processes.

Questions

1. Which carbohydrates (and fibres) do AFSSA's recommendations target?
2. What carbohydrate and fibre analyses need to be performed, with regard to the components whose consumption should be increased or decreased, according to the recommendations?
3. Can an analytical procedure or a specific definition be used to distinguish between simple carbohydrates that are "intrinsic" to basic ingredients and "added" simple carbohydrates?
4. What recommendations should be made for the substitution of simple carbohydrates added during preparation; and what deviations from the recommendations will need to be prevented and/or controlled?

Expert assessment method

After consulting with the Scientific panel on human nutrition, which met on 28 September and 23 November 2006, AFSSA is issuing the following opinion:

1. Definition of carbohydrates

Carbohydrates are alcohols with an aldehyde (CHO) or ketone (CO) functional group. Most carbohydrates have the basic formula $(CH_2O)_n$ where $n \geq 3$.
Carbohydrates are generally classified by their degree of polymerisation (DP): monosaccharides (DP=1), disaccharides (DP=2), oligosaccharides (2<DP<10) and polysaccharides (DP≥10).
AFSSA (AFSSA, 2004 a) also makes a distinction between simple (mono- and disaccharides) and complex carbohydrates.
From a regulatory standpoint, the term "carbohydrates" means any carbohydrate which is metabolized in man, including polyols, and the term "sugars" means all monosaccharides and disaccharides present in food, with the exception of polyols[1].

2. Consumption and composition data

2.1 Consumption trends[2]

According to the CCAF (French food consumption behaviour) survey that was conducted in 2004 by CREDOC (a research centre that studies and observes living conditions), on average, 45% of a French adult's energy intake is in the form of carbohydrates (of which 36% is simple carbohydrates). For children, this figure is 49.7% (of which 45% is simple carbohydrates).
A comparison of the results of the ASPCC (sugar-sweetened products, consumption, communication) survey in 1994, the INCA (individual and national study of food consumption) survey in 1999 and the CCAF survey in 2004 shows that the overall percentage of energy consumed by children and adults in the form of carbohydrates increased between 1994 and 2003; whereas the share of simple carbohydrates in total carbohydrate intake noticeably decreased between 1999 and 2003. It should be noted however that there are methodological differences between these surveys, which means that hasty conclusions regarding consumption trends should not be drawn from these data. AFSSA (AFSSA, 2004 a) stated, based on the ASPCC and INCA studies, that "simple carbohydrate intakes are increasing […] and the contribution of simple carbohydrates in energy intakes is increasing". There was therefore a slight shift in French consumption of simple carbohydrates between the INCA study and the CCAF study (data unavailable when the report was published).
The conclusions of the CCAF survey (2004) confirm a previously-observed trend, i.e. a contribution of simple carbohydrates to alcohol-free energy intakes higher in adult women than in adult men (this is not the case for children).
The main foods contributing to children's and adults' simple carbohydrate intakes, according to this survey's data, are presented in Table 1.

Food groups	Children	Adults
Sugar, jam, honey, syrup, etc.	6.6	15.9
Chocolate, chocolate confectionary bars, sweets	5.9 + 1.9 = 7.8	2.2 + <1.8**
Pastries, sweet biscuits	7.0 + 4.0 = 11.0	8.2 + 2.0 = 10.2
Ice cream, sorbet, frozen bars	2.4	<1.8**
Breakfast cereals	6.7	<1.8**
Bread, rusk	<1.9**	4.2

[1] French Decree no. 93/1130 of 27 September 1993, Articles 4.IIIb and c on labelling related to the nutritional qualities of foodstuffs
[2] Data taken from an ASPCC-CREDOC presentation in a carbohydrates working group meeting chaired by the DGAL.

Food groups	Children	Adults
Sweetened beverages (fruit juices and nectars, sodas)	10.1 + 8.5 = 18.6 sodas: 13.6% for children aged 15-20	4.5 + 5.5 = 10.0
Hot beverages	5.3	3.8
Milk, Yogurts and fermented milk, Yogurt drinks and Actimel	4.7 + 7.9 + 2.2 = 14.8	<1.8** + 7.0 + <1.8**
Dessert creams and flans, Rice pudding, mousse, clafoutis, tiramisu, etc.	3.1 + <1.9**	3.2 + 2.0 = 5.2
Soups	<1.9**	2.1
Fresh fruits, Vegetables (excl. potatoes)	8.4 + 2.1 = 10.5	15.8 + 4.0=19.8
Compotes and stewed fruits	2.4	1.8
Mixed dishes	2.2	3.8
Alcoholic beverages		3.3
Total simple carbohydrates (Sum of contributions/TSC***)**	**(≥)91.4/104*** **	**(≥)89.3/86*** **
For an average energy intake in kcal/day	*1864*	*2171*

Table 1: Contribution of the main food groups consumed to daily simple carbohydrate intakes in children and adults (% of total simple carbohydrate intakes) (according to the CREDOC-CCAF survey – 2004)

* CREDOC/CCAF survey, 2003/2004

** Data on these foods were not given in the ASPCC-CREDOC presentation. These foods are not among the (18 for children and 17 for adults) major vectors of simple carbohydrates for children and adults; the figures 1.9 (for children) and 1.8 (for adults) are the contributions of foods that contribute the least to simple carbohydrate intake for children and adults, respectively;

*** These figures indicate average consumption of total simple carbohydrates for an average energy intake of 1864 kcal/day (for children) and 2171 kcal/day (for adults).

However, AFSSA notes, for the adult population, an obvious inconsistency between these figures and those calculated from contributions of foods to simple carbohydrate intakes.

2.2 Simple carbohydrate content of the main carbohydrate-containing food groups

The data given in the section below were provided by manufacturers from the various sectors involved within the framework of the working group on carbohydrates chaired by the DGAL.

In **rusk and bread products**, 2,814 tonnes of sucrose were used in 2004, versus 42 tonnes of glucose and isoglucose syrups, 87 tonnes of other syrups (inverted sugar and sugar blends), 292 tonnes of other "sugars" (including dextrose, glucose, maltose, fructose and maltodextrins), 52 tonnes of honey and 18 tonnes of polyols. Moreover, the average proportion of sucrose in bread products and packaged toasts is 5 kg for 100 kg of flour.

On average, **biscuits** contain 43% cereals and 24% sweeteners. These sweeteners are broken down as follows: 75% sucrose, 18% glucose and isoglucose syrups, 4% other "sugars", 1% other syrups, 1% polyols and very low quantities of honey. The percentage of simple carbohydrates in biscuit ingredients varies from one product to another. For example, between dry and soft biscuits, the average simple carbohydrate/starch ratio varies from 0.44 to 4.77.

On average, **breakfast cereals** contain 62% cereals and 24% sweeteners, which are broken down as follows: 93% sucrose, 4% honey and 3% glucose and isoglucose syrups. Simple carbohydrate/starch ratios are respectively 0.03 and 0.11 for oatflakes and cornflakes and may exceed 0.7 for most cereals more specifically aimed at children (chocolate-flavoured, honey-flavoured, caramel-flavoured, chocolate-filled cereals, etc.).

Chocolate contributes respectively to 5.4 and 2.1% of simple carbohydrate intakes in children and adults.

On average, dark chocolate and milk chocolate contain 48% cocoa-based products and 34% sweeteners (of which 89% sucrose, 8% glucose and isoglucose syrups and 3% "other sugars"). Chocolate's carbohydrate content varies from 28 g/100 g for dark chocolate to 66 g/100 g for chocolate confectionary bars. The majority of these foods have a carbohydrate content higher than 50%. As chocolate contains little water and relatively little protein (between 5.6 and 10 g/100 g), chocolates with the fewest carbohydrates contain the most fat; that is the case of dark chocolate, with 45.4 g fat per 100 g. Aside from chocolate confectionary bars, most chocolates contain more than 30 g fat per 100 g. The use of bulking sweeteners (polyols) and intense sweeteners is authorised in "no added sugar" and "reduced energy" chocolates.

On average, **sweets** represent a limited contribution to the simple carbohydrate intake of adults (0.6 g/day) and children (2.5 g/day). Children who consume large amounts of sweets consume an average of two pieces per day. Sweeteners make up 76% of these products on average, and are broken down as follows: 45% sucrose, 37% glucose and isoglucose syrups, 10% honey, 5% other simple carbohydrates and 3% other syrups.
"Sugar-free" sweets are experiencing tremendous success. In supermarkets, "sugar-free" products account for 91% of chewing gum sales and 60% of small pocket sweet sales. In these products, simple carbohydrates are primarily replaced with polyols and intense sweeteners. Their energy value is considerably lower (228 kcal/100 g) than that of traditional sweets (379 kcal/100 g). These sweets are smaller than their traditional counterparts. Each "serving" therefore has a low energy value (around 1 kcal).

Seventeen percent of **dairy products** do not contain any simple carbohydrates: these are butter and matured cheeses (which contain no lactose after fermentation). In milk and cream (55% of dairy products), lactose is the only carbohydrate source. In the "fresh dairy product" group (28% of all dairy products), which includes yogurts and other fresh fermented milk, fromage frais and dessert creams, 39% of products contain lactose only (plain yogurt, Petit Suisse, etc.) and 61% also contain added sweeteners. In total, only 17% of dairy products contain added sweeteners. Yogurts and fermented milk represent the fourth contributor to the simple carbohydrate intake of children and adults. Dessert creams and flans, as well as yogurt drinks, are respectively in 12th and 16th position among the products contributing to simple carbohydrate intakes (Source: CCAF, 2004).
Milk, which is the base ingredient in dairy products, contains lactose, the only simple carbohydrate in plain varieties (3 to 4 g/100 g in the finished product). The fruits added to some yogurts and fermented milks also contribute simple carbohydrates (namely fructose) but in small quantities. Sucrose is the primary simple carbohydrate added to "sweetened" dairy products. However, depending on the technological properties, and the recipe's needs, glucose and fructose, and possibly even glucose and fructose syrups, can also be used.

Sweetened beverages make up a significant source of simple carbohydrates, particularly for children. These beverages include firstly fruit juices and nectars, and secondly soft drinks. Soft drinks contain, according to the French soft drink association, 8 to 12 g/100 mL simple carbohydrates (generally sucrose). Fruit juices contain 8 to 15 g/100 mL (the average is 10 g/100 mL, according to the REGAL table, Favier *et al.,* 1995) and nectars contain 10 to 16 g/100 mL (the average is 13 g/100 mL, according to the REGAL table, Favier *et al.,* 1995). "Diet" soft drinks do not contain added simple carbohydrates but rather intense sweeteners. Soft drinks account for 11% of all beverages consumed in France, with the exception of tap water. Over the past few years, the market has seen the arrival of beverages with both intense sweeteners (less than that found in "diet" soft drinks) and low amounts of sugars.

The majority of **fresh fruits** contain 5 to 20% simple carbohydrates (Shallenberger, 1974). A raw apple (skin on) contains approximately 10.4 g total sugars, including 5.9 g fructose, 2.4 g glucose and 2.1 g sucrose (USDA, 2005). The dominant simple carbohydrate varies by species and variety. For example, sucrose is dominant in apricots and peaches, whereas fructose is dominant in apples, grapes, pears, cherries and strawberries. Glucose is also abundant in grapes, cherries and strawberries (Shallenberger, 1974).

Jams, compotes and fruit preserves contain the fruit's intrinsic simple carbohydrates (fructose, sucrose and glucose for the most part, but also other minor simple carbohydrates such as maltose) and added simple carbohydrates, with the exception of fruit purees and "natural" fruit preserves. The percentage of simple carbohydrates varies from less than 16% for lightly sweetened fruit purees to more than 60% for jams. Compotes contain 24 to 40% simple carbohydrates. The "added simple sugars" used are, depending on the product, sucrose, glucose-fructose, glucose or fructose syrups, or dextrose.

Sucrose remains, to date, the primary sweetener consumed by the French population.

2.3 Carbohydrate sweeteners and artificial sweeteners

The food processing industry uses sucrose and syrups produced from starch hydrolysis as its primary sweeteners.
The partial substitution of sucrose with these starch hydrolysates is related, in general, to their technical and functional advantages. The “cost” parameter can also explain some substitutions, as sucrose costs around twice as much as glucose syrup. However, these sweeteners are still a minority of all those used in sweetened foods.
Furthermore, there has been a steady rise in the use of intense sweeteners, sometimes combined with bulking agents, and of other substances presented in Table 2. These include sweeteners made from plant-based products, which are primarily used to sweeten spirits, such as fresh or concentrated grape must, rectified concentrated grape must and carob syrup.

Sweetener	Sweetening power	Glycaemic index	Chemical composition
Lactose	30	46±2	Galactose β 1-4 glucose
Glucose syrup	50-60		Glucose, fructose, maltose (>10%) and DP>2; DP>10 (<40%)
Dextrose	70	100	Pure glucose obtained through starch hydrolysis
Maltose	36-57	105	Glucose α 1-4 glucose
Maltotriose	≈0.25	?	$(Glucose)_3$; α 1-4
Glucose-fructose	75		
Isoglucose (42% or 55% fructose)	# 90-100		Glucose, fructose (>10% of total carbohydrates)
Sucrose	100	68±5	Glucose α 1-2 fructose
Fructose	130	19±2	
Maltodextrins	*# 0*		*$(Glucose)_n$; α 1-4 and α 1-6*
Honey	69.2±8.1-74.1±8.2**	*73*	*Fructose, glucose (2 main sugars), maltose, sucrose and other compounds*
Xylitol (E967)	≈100	8***	$HO-CH_2-(CHOH)_3-CH_2-OH$
Mannitol (E421)	≈50	≈ 0	$HO-CH_2-(CHOH)_4-CH_2-OH$
Sorbitol (E420)	≈50	≈ 0	$HO-CH_2-(CHOH)_4-CH_2-OH$
Isomalt (E953)	≈50	≈ 0	Glucose α 1-6 sorbitol (or mannitol)
Lactitol (E966)	≈40	2***	Galactose β 1-4 sorbitol
Fructooligosaccharides (FOS)	*# 0*	*0*	*$(Glucose)_{n'}$-$(Fructose)_n$; α 1-4 and α1-6; n'=1 or 0; n=2 to 4 and n'=1 for synthetic FOS and n=2 to 10 with an average of 4 and n'=0 for FOS derived from inulin*
Acesulfame potassium (K) (E 950)	13000-20000	0	Dihydro-oxathiazine-dioxyde
Aspartame (E 951)	# 20000	0	Aspartylphenylalanine methyl ester
Cyclamate (E952)	3000-5000	0	Ca or Na cyclamate
Neotame	700000-1300000	0	N-[N-(3,3-dimethylbutyl)-L-α-aspartyl]-L-phenylalanine 1-methyl ester
Neohesperidin dihydrochalcone (DC) (E 959)	40000-60000	0	Dihydrochalcone flavanone
Saccharin (E954)	30000-50000	0	Ortho-sulfobenzoic acid
Sucralose (E 955)	60000	0	Chlorinated derivative of sucrose – Chemical formula: $C_{12}H_{19}Cl_3O_8$
Thaumatin (E 957)	200000-300000	0	Mixture of two proteins isolated from an African tropical fruit

Table 2. Sweetening power and glycaemic index of some carbohydrate sweeteners and intense sweeteners

*GI: reference 100 for pure glucose
** Ischayek & Kern, 2006
*** Foster-Powell *et al.,* 2002; Natah *et al.,* 1997
in italics: carbohydrate substances with no or very little sweetening power

Sucrose

The primary sweetener used in foods intended for human consumption is still, and by a very long way, sucrose (referred to as “sugar” by consumers and manufacturers). It is made from sugar beet or sugar cane, which respectively accounted for 30 and 70% of the world’s sucrose production in 2000 and 2001.

Sucrose is a major sweetening ingredient in the food processing industry, and plays many technological and functional roles in foods such as sweet breads, breakfast cereals, chocolates, etc. It is also a flavour enhancer, is responsible for the Maillard reaction and enables prolonged storage of finished products.

Glucose (or dextrose)

Glucose is an energy substrate that is essential to many organs. It is absorbed quickly, and insulin is secreted almost simultaneously in response to elevated blood concentrations of glucose. Absorbed glucose comes from dietary free glucose, sucrose and maltose (two carbohydrates hydrolysed on the intestinal brush border) as well as starch and maltodextrins (which come from starch).

Dextrose is pure glucose obtained from complete starch hydrolysis. Its degree of polymerisation is therefore 1 whereas its “dextrose equivalent” (DE) is 100. Dextrose in anhydrous or monohydrate form (1 water molecule per glucose molecule) is used particularly in bread and pastry making and ice cream production. More hygroscopic than sucrose, dextrose is used more frequently in soft/moist products. However its sweetening power is lower than that of sucrose, and it produces a sensation of freshness .

Fructose (or levulose)

Fructose is the dominant sugar in fruit as a whole. It is particularly abundant in some species such as apples. However, a fruit’s fructose content depends on its degree of ripeness and can also vary with weather conditions prior to harvest. Moreover, fructose is the main sugar in honey, before glucose.

This sugar has a low glycaemic index and a higher sweetening power than sucrose. That is why it can be used as a sucrose substitute in the diets of diabetics. However, according to present knowledge, it appears that replacing sucrose with fructose only moderately benefits the patient’s glycaemic control and does not alter his/her lipid profile (Thissen & Hermans, 2002).

Furthermore, excessive fructose consumption, although it is not possible to define a specific dose, which depends on individual susceptibility, can raise cholesterol and/or triglyceride levels.

Lactose
Lactose, a carbohydrate of animal origin, has little sweetening power in comparison with sucrose. Manufacturers do not use it as a sweetener in foods.

Glucose syrups and glucose-fructose syrups or isoglucose
These syrups are obtained from a starch milk that successively undergoes liquefaction, saccharification, isomerisation (for syrups containing fructose), several stages of purification and then concentration followed by drying. These syrups are characterised by:

- their ”dextrose equivalent” (DE) which expresses the starch’s degree of hydrolysis. The more advanced the hydrolysis, the more free dextrose (glucose) there is and therefore, the higher the DE value;
- their carbohydrate profile, and particularly their fructose content. The fructose in glucose-fructose syrups (including isoglucoses) is obtained through glucose isomerisation but can also come from the incorporation of other sugars (sucrose or fructose syrup);
- their attractive functional properties: less tendency to crystallise than sucrose and greater resistance to desiccation.

Glucose syrups are made of glucose (DP 1), fructose (DP 1), maltose (DP 2) and glucose polymers with higher DPs. The proportion of DP 1 and 2 molecules is greater than 10% of the total carbohydrates, whereas DP>10 glucose polymers do not exceed 40% of the total carbohydrates. The DE of glucose syrups lies strictly between 20 and 100.

Starch hydrolysates with a DE below 20 are called **maltodextrins**. They have no sweetening power but can act as bulking substances in the presence of intense sweeteners. Their composition includes 1 to 9% DP 1 and 2 molecules and 40 to 99% DP>10 molecules. According to Macdonald & Williams (1988), maltodextrins (DE 5 to 20) are as hyperglycaemic as glucose and maltose. Insulin responses are dose-dependent. The functional properties of glucose syrups vary according to their DE. Like sucrose, they promote browning and improve friability. In addition, some of the technical-functional properties of glucose syrups are different from those of sucrose: they can alter a product’s sweet taste, prevent sucrose from crystallising, improve a filling’s softness and contribute cohesion.
In **isoglucose**, part of the glucose has been converted into fructose through isomerisation. Its DE is between 60 and 100. Primarily used in non-alcoholic beverages, it is also called “high-fructose corn syrup” (HFCS) or “glucose-fructose syrup”. According to the regulations, its fructose content must be greater than 10% of its total carbohydrates. Its production is limited by quotas (507,680 T in Europe, versus 17,440,537 T for sucrose and 320,718 T for inulin syrup).
Isoglucose is used for its functional properties and its sweetening power, which is similar to that of sucrose.

Production of starch hydrolysates (glucose syrups, dextrose, maltodextrins, isoglucose and glucose-fructose mixtures), which was stable (around 335,000 T) until 1997, rose significantly in 1998 (391,000 T) and then in 2000 (421,000 T). It has remained stable ever since[3].

Inverted sugar
Inverted sugar is obtained through the total or partial hydrolysis of sucrose with invertase. It is therefore made of glucose/fructose (50/50) or of ternary mixtures of sucrose, glucose and fructose. It prevents syrups, doughs and fondants (fillings) from drying out. Its metabolic fate is that of the simple carbohydrates that comprise it.

Honey, concentrated fruit juices, fruit preparations
Honey is primarily made of simple carbohydrates: 76% in fresh matter, or 95% in dry matter, according to the REGAL table (1995). These carbohydrates are mainly fructose and glucose (approximately 38 and 31% of fresh matter) but also maltose (7%) and sucrose (approximately 1%). Aside from simple carbohydrates, it contains carbohydrates with heavier molecular weights, a very low amount of protein, including free amino acids, minerals (around 0.3%), vitamins, fats (triglycerides and fatty acids, including palmitic, oleic and linoleic acids), trace elements and infinitesimal quantities of numerous other substances (approximately 200 different compounds). It contains bacteriostatic substances and other substances, such as flavonoids and phenolic

[3] According to the AAC (Association des Amidonniers de Céréales de l’UE), data available up to 2004

compounds, whose biological activity is highlighted by honey producers. Its sucrose and water content affects its crystallisation.

Concentrated fruit juices are also sweeteners as fruit pulp contains, depending on the fruit, between 75% and 85% of simple carbohydrates in the fruit's dry matter. The most abundant carbohydrates in fruits are glucose, fructose and sucrose, but their respective proportions depend on the species and on the degree of ripeness. For example, apples contain approximately twice as much fructose as each of the other sugars (5.6% fructose, 1.83% glucose and 2.66% sucrose, according to Li *et al.,* 2002), whereas oranges contain more sucrose (4.46 g/100 g) than fructose (2 g/100 g) and glucose (1.88 g/100 g). Green grapes - at least some varieties - contain very little sucrose but as much glucose as fructose (Li *et al.,* 2002). Conversely, other species (mangoes, carrots) almost exclusively contain sucrose. In a study on fruits from Hong Kong (58 different species), the glucose/fructose ratio varies from 0.36 to 2.16 (Ko *et al.*, 1998).

Other **fruit preparations** are increasingly being used by manufacturers, following recommendations to reduce added simple carbohydrates. Depending on their formulation, these preparations contain only the simple carbohydrates in the fruits they use, or the latter plus other sweeteners. As fruits have extremely high water content, cooking concentrates their pulp and intrinsic carbohydrates as well as any added simple carbohydrates.

Rectified concentrated grape must is defined by EEC Regulation no. 1493/99. It is available in the form of a colourless, natural glucose and fructose syrup. More than 65% of its fresh matter is simple carbohydrates. It contains, in addition to simple carbohydrates, non-carbohydrate compounds such as polyphenols.

Polyols or sugar alcohols

Six polyols are authorised as additives in foodstuffs intended for human consumption (European Directive 94/35/EC): sorbitol, mannitol, xylitol, maltitol, lactitol and isomalt. Energy values differ from one polyol to another (8.5 to 17 kJ/g), but to facilitate nutritional labelling, the EEC has set a mean value of 10 kJ/g for all polyols versus 16.72 kJ/g for sucrose. They have a very low or nil glycaemic index and are therefore of certain interest for (?) diabetics (Natah *et al.*, 1997). They are also less cariogenic than sucrose, starch derivatives and fructose. Their benefits however are limited by side effects (laxative) at high doses (Thissen & Hermans, 2002). Their quantity is not restricted (based on the *quantum satis* principle), but their use is restricted to specific foodstuffs. They are not authorised in foods intended for children under three or in beverages. Moreover, the label must indicate that "excessive consumption may have a laxative effect".

Intense sweeteners or artificial sweeteners

Sweeteners are food additives used to give a sweet taste to foodstuffs. Their use is regulated in the European Directive 94/35/EC transposed into French law by the 2 October 1997 Order. The use of sweeteners in a food is authorised in:

- foodstuffs "with no added sugar", i.e. without any added mono- or disaccharides or any other ingredient used for its sweetening properties;
- "energy-reduced" foodstuffs, i.e. foodstuffs with an energy value reduced by at least 30% compared with the original foodstuff or a similar product;
- foodstuffs intended for particular nutritional uses in the sense of the 29 August 1991 Decree.

The regulations authorise their use in chocolates and sweets. To date, the biscuit, bread and breakfast cereal industries can use them only in certain foods, such as reduced-energy or "no added sugar" cereal-based desserts or breakfast cereals with a fibre content of at least 15%, fine bakery products intended for particular nutritional uses and starch-based cocktail crackers.

Intense sweeteners, the most well-known of which are aspartame, acesulfame K and saccharin, have much higher sweetening powers than carbohydrate sweeteners. When they are intended to replace these caloric compounds, a very small quantity of them is added and they are generally combined with a bulking substance that is "neutral" from an organoleptic viewpoint but that contributes volume. These bulking substances have no sweetening power and when they are made with carbohydrates, they may be either low-calorie or calorie-free (polydextrose, cellulose), or as caloric as sweeteners made from carbohydrates (maltodextrins).

The term "intense sweeteners" groups together a wide range of products, which may be plant-based or obtained through chemical synthesis, that have a sweetening power several dozen to several thousand times greater than that of sucrose. Added in small quantities, they deliver a sweet taste but do not contribute bulk or texture. Apart from beverages, where water is the "bulk", the majority of foods require the use of bulking agents in combination with intense sweeteners. Like polyols, some intense sweeteners are authorised in Europe as additives in foodstuffs intended for human consumption (European Directive on sweeteners, 94/35/EC, see Table 3): aspartame, acesulfame potassium, saccharin and its salts, cyclamic acid and its salts, thaumatin, neohesperidin dihydrochalcone, sucralose and aspartame-acesulfame salt. A maximum value is set for their use which varies depending on the sweetener and the category of food. Manufacturers are increasingly using mixtures of two and even three different sweeteners that act in synergy and produce sweetness, stability and solubility when combined.

Sweetener	ADI* (mg/kg body weight)	Caloric value	Potential risks
Acesulfame K (E 950)	0-9	0	
Aspartame (E 951)	40	#0	For PKU patients
Cyclamate (E 952)	7	0	
Neohesperidin DC (E959)	0-5	0	
Neotame**	0.6***	0	
Saccharin (E954)	5	0	
Sucralose (E 955)	0-15	0	
Thaumatin (E 957)	Not specified****	#0	

Table 3. Intense sweeteners approved by the European Union

* Acceptable Daily Intake set by the JECFA (Joint FAO/WHO Expert Committee on Food Additives)
** This sweetener has not yet been authorised in the European Union
*** The Acceptable Daily Intake set by the JECFA (Joint FAO/WHO Expert Committee on Food Additives) is 2 mg/kg bw. The provisional Acceptable Daily Intake of 0.6 mg/kg bw was defined by AFSSA.
****According to the European Commission's Scientific Committee on Food (SCF)

Aspartame is an esterified artificial dipeptide (aspartylphenylalanine methyl ester) commonly used in "low-calorie" and "diet" foods. It cannot however be used in all foods as it is at least partially destroyed by some technological treatments. High-pressure and high-temperature treatments and/or those with an acidic pH lead to the appearance of unsweetened compounds (aspartylphenylalanine and diketopiperazine) (Butz *et al.*, 1997). In a report (AFSSA, 2000), AFSSA "considers that based on current scientific data, a relationship cannot be established between exposure to aspartame and brain tumours in humans or animals". This opinion was confirmed by various assessments including that of the European Scientific Committee on Food, which was made public in December 2002. Moreover, EFSA recently confirmed that the acceptable daily intake of aspartame is 40 mg/kg body weight and that it is safe to use[4]. The regulations[5] stipulate that labels on food products that contain aspartame must include the following warning: "contains a source of phenylalanine".

Acesulfame K is a non-caloric sweetener that was discovered in 1967. It has a long shelf life and resists heat well. It enhances and reinforces certain flavours and has synergic action when combined with other low-calorie sweeteners. It can be used in a very wide range of foods (beverages, dairy products, sweets, pastries, tinned fruits and vegetables, etc.). The numerous safety studies that have been carried out have not revealed any adverse effects (ISA, 2001).

Saccharin is one of the oldest sweeteners in use in Europe. It was discovered in 1879. Its field of application is extremely wide because it is very stable, including during cooking. Saccharin is absorbed slowly. It is not metabolised and is rapidly excreted as is by the kidneys. Since the 1960s and 1970s, it has been used less and less, for the benefit of aspartame in particular.

Cyclamate was discovered in 1937. Its sweetening power is only 30 to 50 times higher that of sucrose, but it works in synergy with most other low-calorie sweeteners such as acesulfame K and aspartame. It is calorie-free but is very partially metabolised in some individuals' intestines. In general, its intestinal absorption is highly limited and, if it is absorbed, it is excreted as is by the kidneys (ISA, 2001).

[4] Opinion of the Scientific Panel on Food Additives, Flavourings, Processing aids and Materials in contact with Food (AFC) on a new long-term carcinogenicity study on aspartame. *The EFSA Journal* 356: 1-44, 2006.
[5] The French 2 October 1997 Order on additives that may be used to produce foodstuffs intended for human consumption

Sucralose is a sweetener derived from sucrose that can hydrolyse in a solution but only at a very acidic pH and a very high temperature. It is used in a wide range of products such as table sweeteners, beverages, desserts (including frozen desserts) and dairy products. It is not metabolised in humans (ISA, 2001).

Thaumatin is a low-calorie protein sweetener extracted from the Katemfe fruit (Thaumatococcus danielli) from West Africa. Thaumatin is a sweetener that acts as a flavour modifier, masking bitterness and adding palatability. It is frequently used in combination with other intense sweeteners in beverages, chewing gums, yogurts and dairy products. Thaumatin is metabolised by the body like a dietary protein (ISA, 2001).

Neohesperidin DC is a calorie-free sweetener as well as a flavour enhancer. It is produced through the hydrogenation of neohesperidin, a flavanone found naturally in bitter orange peel. A very small amount of it is often used in combination with other sweeteners. It is highly stable at an acidic pH, including in solutions, and during heat treatments, which makes it an option for sweetening products that are subject to pasteurisation or UHT processes. It is primarily used, in conjunction with other sweeteners, in sweets, beverages and milk products. Only a very small quantity of neohesperidin DC is absorbed. The intestinal flora converts it into metabolites that are identical or similar to those derived from hydrochalcones arising from natural flavanones.

Neotame is an N-[N-(3,3-dimethylbutyl)-L-α-aspartyl]-L-phenylalanine 1-methyl ester that is synthesised in one step when reductive alkylation reacts in the presence of 3,3-dimethylbutaraldehyde. It can generate degradation products at extreme pH levels and/or temperatures, but the absence of toxicity of these substances has been proven. This sweetener was the subject of two AFSSA opinions (AFSSA, 2004 b; AFSSA, 2005 a), which concluded that:

- there is no risk for consumer health (at the concentrations and using the applications proposed by the petitioner), with a provisional ADI of 0.6 mg/kg body weight;
- there is no need to mention the risk for PKU patients.

To date, this sweetener has not been authorised in France or in the rest of Europe.

3. Answers to questions

AFSSA insists on the fact that the answers given below fall within the very specific framework of this request. Concerning the definition of the degree of polymerisation (DP), which characterises molecules whose consumption should be reduced, AFSSA followed the request's recommendations: "the agreed on DP must be acceptable from a technological viewpoint to ensure it is taken into consideration when all the concerned food processing industries optimise the composition of their foods". The assessment therefore considered not only the current state of scientific knowledge, but also the technological constraints affecting the possibilities of analysing various ranges of DP.

1. <u>Which carbohydrates (and fibres) do AFSSA's recommendations target?</u>

AFSSA considers that the carbohydrate substances whose consumption should be encouraged are:

- total fibres;
- starch.

Carbohydrate sweeteners do not have any major advantages over simple carbohydrates, particularly sucrose, in terms of calorie content and metabolic and physiological effects (glycaemic and insulin responses) (Table 5).

As a result, **AFSSA considers that these sweeteners should be included in the carbohydrates whose consumption should be reduced.**

The carbohydrates concerned are:

- simple carbohydrates (DP 1 and 2);
- oligosaccharides and other derivatives of DP>2 carbohydrate polymers that may have sweetening power (particularly those found in glucose syrups and other preparations containing carbohydrate mixtures with a low DP). A maximum DP of 5 could be set, given that above this level, the sweetening power becomes very low (≤10% of sucrose's

sweetening power for maltooligosaccharides with a DP ≥ 6) (Kimura *et al.*, 1990). This proposal is based on the assumption that DP>5 carbohydrate molecules with sweetening powers less than 10% of that of sucrose would currently be of little interest to the food processing industries;
- oligosaccharides with a DP greater than or equal to 6 and maltodextrins, which do not have any sweetening power but may cause insulin secretion equal to or greater than that of simple carbohydrates.

2. What carbohydrate and fibre analyses need to be performed, with regard to the components whose consumption should be increased or decreased, according to the recommendations?

In light of the data presented in the previous section, AFSSA is proposing that the carbohydrate and fibre analyses to be performed as part of the study aimed at tracking changes in the consumption and supply of "sweetened" foods should include the following molecules:

Carbohydrates whose consumption should be encouraged:
- “real” starch, whose measurement excludes simple carbohydrates and dextrins with a DP<10-14 (approximately);
- total fibres (soluble + insoluble);
- resistant starch, which will not be accurately quantified in the analysis of total fibres; in this case, it will be necessary to quantify the residual starch in the “fibre” fraction determined using the Association of Analytical Chemists (AOAC) 985.29 or 991.43 method which should be deducted from the total fibre content;
- carbohydrate polymers considered as “dietary fibres” but not quantified by the “total fibres” analysis method; these are, to date, fructooligosaccharides, oligofructoses and polydextrose.

Carbohydrates whose consumption should be reduced:
- simple carbohydrates (DP 1 and 2);
- oligosaccharides and other derivatives of 2<DP<6 carbohydrate polymers, whose bonds are hydrolysable by human endogenous enzymes;
- maltodextrins that are used as bulking substances in foods containing intense sweeteners;

Moreover, quantification of the 4 dominant -oses in dietary fibres and their respective proportions could be used, in the majority of foods, to monitor the nature of the fibres (intrinsic to the raw materials or added).

The analytical methods used to quantify these molecules are presented in Table 4.

Carbohydrate component	DP	Recommended method	
		Reference	Principle
Mono- and disaccharides	1 & 2	Dekker, 2000; FAO/WHO, 1998; DIONEX®, 2000; ¤Moreno *et al.*, 1999	HPLC* (HPAE-PAD*)
Oligosaccharides	3-9		HPLC (HPAE-PAD*)
Maltodextrins	3-9		HPLC (HPAE-PAD or HPAE-PED*¤)
Total “real" starch	>9	AOAC method 996.11 AACC method 76-13 (McCleary *et al.*, 1997)	Enzymatic method (amyloglucosidase then glucose determination); Specific assay; in parallel, maltodextrins and simple carbohydrates make it possible to determine “real” starch; By default, it is possible to estimate simple carbohydrates and maltodextrins by extraction in ethanol 80% (DP<10-14, approx.) and glucose assay after amyloglucosidase hydrolysis
Resistant starch	>9	AOAC 2002-02 McCleary & Monaghan, 2002	Enzymatic method

Carbohydrate component	DP	Recommended method	
		Reference	Principle
Soluble and insoluble fibres**	>9	AOAC 985.29; AOAC 991.43 (Prosky *et al.*, 1985; Lee *et al.*, 1992)	Gravimetric enzymatic methods
-oses that make up dietary fibres		Englyst *et al.* (1994)	Chromatography methods (GC or HPLC)

Table 4. Recommended methods for each carbohydrate category to be analysed

*HPLC: High Performance Liquid Chromatography; HPAE-PED: High Performance Anion-Exchange chromatography with Pulsed Electrochemical Detection

** See AFSSA, 2004 c

Enzymatic methods are presently available to specifically measure mono- and disaccharides. But, unlike with chromatography methods, these measurements cannot be taken at the same time on the same sample.

Gas chromatography (GC) could be used for the measurement of -oses but the sample needs to undergo chemical treatment to convert the carbohydrates into volatile compounds, which limits its scope of application to monosaccharides. This is because some -oses are modified by this treatment and therefore cannot be accurately measured (example of fructose reduced into mannitol). Polymers must be hydrolysed before being measured by GC; although the technique enables component –oses to be identified, it cannot determine the DP of polymers.

High Performance Liquid Chromatography (HPLC) is less restrictive as it supplies a wide range of media from which, depending on the polarity and/or size of the solutes, complex mixtures can be analysed with a minimum amount of preparation. Two methods are useful here, normal-phase chromatography on silica with amino functional groups and ion-exchange chromatography.
For example, the analysis of mono- and disaccharides on aminopropyl-grafted silica columns (normal phase) is commonly practiced today. However, this analysis, which calls for the use of an eluent made of a binary mixture, usually acetonitrile/water, often has limited performance due to refractometric detection that involves isocratic elution. Note that replacing a refractometer with an Evaporative Light Scattering Detector (ELSD) makes it possible to work in gradient mode with improved sensitivity (around 0.1 µmole). The use of gradient mode optimises separations of simple carbohydrates and enables oligosaccharides to be analysed. A vast selection of literature is available on the topic and most column manufacturers provide data sheets describing the system's potential, phase NH_2 – ELSD, for the analysis of mono-, di- and oligosaccharides in foods. These analyses however are easily disrupted and columns are contaminated by the presence of mineral salts, proteins, amino acids and even oligosaccharides with DPs that are too high.

Ion-exchange chromatography offers two possibilities: cation exchangers, effective in separating mono- and disaccharides, but very fragile to use, and anion exchangers, and more particularly the porous supports made of latex microbeads functionalised by quaternary amines. This type of medium, which is perfectly inert vis-à-vis pH and ionic strength variations, means that very basic eluents can be used (NaOH from 0.015 to 0.5 M). Under these conditions, neutral molecules, which have pKa values between 12 and 14, will have their alcohol functions partially or totally ionised, and may therefore be separated. This method has the additional advantage that it can be directly combined with pulsed amperometric detection (PAD). Due to the use of a specific potential to oxidise the secondary alcohol functions of carbohydrates, pulsed amperometric detection is a specific method, which has very little sensitivity to the gradient and enables easy-to-interpret chromatograms to be obtained. As it is highly sensitive, given that carbohydrate concentrations of around a nanomole have been detected, it limits sample preparation stages while keeping the column from being polluted by the matrix's various components.

3. <u>How can an analytical procedure or a specific definition be used to distinguish between simple carbohydrates that are "intrinsic" to basic ingredients and "added" simple carbohydrates?</u>

For this to happen, a methodology needs to be defined that can distinguish between simple carbohydrates that are intrinsic to basic ingredients and sweetening carbohydrates added during food preparation.

Two approaches can be used:

- isolation of minor carbohydrate or non-carbohydrate compounds characteristic of the raw material's origin;
- identification of the target carbohydrate based on the isotopic ratios of the components.

The first option requires knowledge of the compounds that may be present and implementation of an appropriate sensitive measurement method.

For the second option, two techniques may be considered:

- IRMS (Isotope Ratio Mass Spectrometry);
- SNIF-NMR (Site-specific Natural-Isotope Fractionation).

For these two techniques, the carbohydrate compound(s) of interest must be isolated by preparative liquid chromatography.
IRMS consists of a mass spectrometry study of the isotopic composition of one of the elements (carbon in general). The product is destroyed by combustion and the analysis is performed on the formed CO_2. The obtained result is therefore global.
SNIF-NMR uses proton or carbon NMR and can be used to determine, insofar as possible, the $^{13}C/^{12}C$ or D/H ratio for each atom in the molecule.
It is the most accurate method, but very few laboratories are capable of mastering it. This method is recognised as an AOAC method (AOAC, 1996; Martin *et al.*, 1996).

It is presently unfeasible to expect such analyses to be performed systematically by manufacturers or inspection authorities.

As an alternative, and in order to provide consumers with relevant information, AFSSA is proposing that all carbohydrate sweeteners be included in the definition of "added sugars".
"Added sugars" may be defined as simple -oses, disaccharides or carbohydrate polymers with a degree of polymerisation (DP) strictly lower than 6, introduced into a food as a pure or refined ingredient, or any other ingredient containing a majority of carbohydrates with these characteristics. These should also meet the following criteria:

1. they are hydrolysed in the small intestine and/or absorbed by some or all healthy adult men and women and/or children over the age of three, and are then at least partially metabolized by these same populations.
2. they have a sweetening power that is 10% higher than that of sucrose.

In terms of nutritional labelling, the claims "no added sugars" and "no added sugar" currently concern foods without carbohydrate compounds whose DPs are higher than 2. The definition of "added sugars" proposed by AFSSA, which takes into account the similar physiological effects of carbohydrate compounds with DPs lower than 6, strictly limits the use of these claims to products that contain no added sweetener.

4. <u>What recommendations should be made to substitute simple carbohydrates that are added during preparation; and what deviations from the recommendations will need to be prevented and/or controlled?</u>

Since AFSSA's report was published (AFSSA, 2004 a), the food processing industries have followed AFSSA's recommendations in order to make claims about eliminating or reducing "added sugars", "added sugar" or "added sucrose". This trend is beneficial to consumers, who can find foods with lower amounts of simple carbohydrates and who are informed by these claims, about the need to reduce their simple carbohydrate consumption.
However, the beneficial food modifications related to these claims should be compared with certain corresponding potential disadvantages, as shown in Table 5 below.

Component	Advantage(s)	Disadvantage(s)	Overall substitution benefit & general comments
Fructose	Less hyperglycaemic than	Potentially hypertriglyceridemic	Less hyperglycaemic than sucrose but

Component	Advantage(s)	Disadvantage(s)	Overall substitution benefit & general comments
	sucrose		risk of hypertriglyceridemia
Glucose/fructose or isoglucose syrup	Glycaemic effect between that of glucose and fructose (depending on the proportion of each sugar)	Disadvantages of each of the two sugars. When 50/50 = sucrose	No health benefits Risk of hypertriglyceridemia related to the presence of fructose
Intense sweetener(s) + maltodextrins	Reduces the overall load of hyperglycaemic carbohydrates	Hyperglycaemic Long-term nutritional effect of intense sweeteners at high doses unknown	Limited to "reduced energy" (-30% energy) and "sugar-free" sweets Long-term nutritional effect of intense sweeteners at high doses unknown
Intense sweetener(s) + calorie-free bulking substance	Totally eliminates carbohydrate intake related to the desired sweetening power	Long-term nutritional effect of intense sweeteners at high doses unknown	
Sugar alcohols	Fewer calories than sugars (2.4 kcal/g) Fight cavities Bulking sweetener (contributes "bulk")	Laxative effect at high doses	Limited to "reduced energy" (-30% energy) and "sugar-free" sweets Risk of diarrhoea (when consumed in large amounts)
Honey	Contains nutrients and molecules with potentially beneficial biological activity (e.g. bacteriostatic, antifungal activities, etc.)	Glycaemic effect similar to isoglucose Contains almost as much energy as glucose syrup (for the same sugar concentration): 290 kcal/ 100 g for 80% sweetener	Energy and GI are almost as high as isoglucose but contributes potentially beneficial molecules
Plant-based fraction rich in fructose and glucose (e.g. rectified concentrated grape must)	–	–	Inform the consumer that it is a source of simple carbohydrates

Table 5. Possible sucrose substitutes – advantages and disadvantages

At the present time, the use of intense sweeteners and polyols is extremely limited since they are authorised only in "reduced energy" and "sugar-free" sweets and "no added sugar" chocolates whereas they are not authorised to be added to biscuits or everyday breakfast cereals. It is therefore necessary to examine the benefit/risk balance related to a rise in the number of food categories in which the incorporation of bulking or intense sweeteners would be authorised. Table 6 presents the advantages and disadvantages of bulking substances that could be added to foods if a greater number of intense sweeteners were introduced.

Bulking substance	Chemical composition	Advantage(s)	Disadvantage(s)	Overall health benefit of substitution & general comments
		For consumer health		
Maltodextrins	Polymer of glucose units linked with α 1-4 and α 1-6 bonds	Because they are combined with an intense sweetener, they replace a greater amount of carbohydrates	4 kcal/g Very hyperglycaemic (same as glucose with identical glucose equivalent content)	Because they are combined with an intense sweetener, they replace a greater amount of carbohydrates.
Polydextrose	Polymer of glucose units linked by several types of bonds (particularly 1-2, 1-3, 1-4, 1-6 α or β) and also containing sorbitol residues and citric acid	No effect on blood sugar Low calorie (1 kcal/g)	–	No effect on blood sugar Low calorie

Cellulose	Polymer of glucose units linked with β 1->4 bonds	No effect on blood sugar Low calorie	–	

Table 6. Bulking substances that may be added to foods if intense sweeteners are introduced on a wider scale

Conclusion

AFSSA is therefore proposing that the following carbohydrates should be introduced in the plan to monitor carbohydrate compositions and intakes:

- **Carbohydrates whose consumption should be encouraged**
    - “real” starch, whose measurement excludes simple carbohydrates and dextrins with a DP<10-14 (approximately);
    - total fibres (soluble + insoluble);
    - resistant starch, which will not be accurately determined in the analysis of total fibres; in this case, it will be necessary to determine the residual starch in the “fibre” fraction measured using the Association of Analytical Chemists (AOAC) 985.29 or 991.43 method which should be deducted from the total fibre content;
    - carbohydrate polymers considered as “dietary fibres” but not quantified by the “total fibres” analysis method; these are, to date, fructooligosaccharides, oligofructoses and polydextrose.

- **Carbohydrates whose consumption should be reduced**
    - simple carbohydrates (DP 1 and 2);
    - oligosaccharides and other derivatives of 2<DP<6 carbohydrate polymers, whose bonds are hydrolysable by human endogenous enzymes; these compounds have a metabolic fate similar to that of simple carbohydrates and have a sweetening power equal to at least 10% that of sucrose;
    - maltodextrins that are used as bulking substances in foods containing intense sweeteners; they do not have any sweetening power but may cause insulin secretion equal to or greater than that caused by simple carbohydrates.

For some types of products, substitution of molecules whose consumption should be reduced could also be studied.
Concerning the use of bulking sweeteners (polyols), AFSSA stresses that additional studies need to be undertaken to determine their tolerance, particularly among children, and individuals with intestinal disorders.
Concerning the use of intense sweeteners, AFSSA considers that a critical and exhaustive study of the scientific literature needs to be conducted to determine the short- and especially long-term nutritional impact of the molecules that are currently authorised in France and Europe.

In order to distinguish between simple carbohydrates intrinsic to basic ingredients and sweetening carbohydrates added during manufacturing, AFSSA is proposing the following definition for the notion of "added sugars":
“Added sugars” may be defined as simple -oses, disaccharides or carbohydrate polymers with a degree of polymerisation (DP) strictly lower than 6, introduced into a food as a pure or refined ingredient, or any other ingredient containing a majority of carbohydrates with these characteristics. These should also meet the following criteria:

1. they are hydrolysed in the small intestine and/or absorbed by some or all healthy adult men and women and/or children over the age of three, and are then at least partially metabolized by these same populations.
2. they have a sweetening power that is 10% higher than that of sucrose.

This definition could be adjusted as the literature is updated.

This DP is compatible with consumers' perceptions according to which the term "sugar" is associated with a sweet taste.

Lastly, AFSSA considers that reducing the sweetening carbohydrate substance content (mono- and disaccharides, glucose and/or fructose syrups, fruit-based sweetening preparations) of certain foods is necessary to achieve the public health objective which is to reduce by 25% the French population's consumption of simple carbohydrates. The methods used to do so may be defined for each food group.

Informational and nutritional education tools explaining the recommendations on sweetened products are to be developed to support this initiative to improve the nutritional quality of products.

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Carbohydrate sweeteners; glucose syrups; added simple carbohydrates; sugars; sweetener; degree of polymerisation

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