# Carbohydrates in human nutrition

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FAO and the World Health Organization (WHO) periodically convene expert consultations on various topics in nutrition to ensure that their knowledge is up to date and to provide advice to member countries. One such consultation was held in April 1997 to review the role of carbohydrates in human nutrition. This resulted in a report (FAO/WHO, 1998) and a number of recommendations which are referred to throughout this article.

## CARBOHYDRATE ANALYSIS

Carbohydrate is the most important food energy provider among the macronutrients, accounting for between 40 and 80 percent of total energy intake. In research on macronutrients to date, the role of dietary carbohydrates in human nutrition has been less extensively studied than those of protein and fat. The main reason for this has been the absence of sound and rapid methodologies because carbohydrate analysis is rather complicated. Considerable progress has been made in the development of methodologies based on gas-liquid chromatography, high performance liquid chromatography and enzymatic analyses, and research interest has grown accordingly. But old habits die hard and, since a value for the carbohydrate content of foods has long been derived "by difference", with apparently satisfactory results, there appears to be little incentive to develop more specificity for routine food composition analyses. However, the traditional method of expressing carbohydrate by difference is problematic because it includes a number of non-carbohydrate components, such as lignin, organic acids, tannins, waxes and some Maillard products. More specificity would be most welcome, and the experts for this consultation expressed the hope that this would develop (see Box 1, recommendations 1 to 8). A recent editorial in the *Journal of Food Composition and Analysis* has also made a plea in that direction (Burlingame, 1999).

## CARBOHYDRATE CLASSIFICATION

The FAO/WHO report provides a classification for the main categories of food carbohydrates based on their degree of polymerization (see Figure). Such an approach is a compromise between a chemical classification and a physiological classification. If carbohydrates were reported on the basis of their chemical nature, according to the scheme proposed, much of the terminology currently used (e.g. for food labelling), which is based on physiological and/or methodological distinctions, could be eliminated. As explained in the report, it is desirable to move away from such terminology because its meanings vary for different regions of the world, and this leads to confusion. For example, the expression "complex carbohydrate" has come to describe starch in North America but, in Europe, it includes all polysaccharides.

## DIETARY FIBRE

The nature of carbohydrates in foods is a growing field of interest within the food industry because of the potential of some types of carbohydrates to help prevent diseases of lifestyle. Non-glycaemic carbohydrates, i.e. those carbohydrates (or their components) that are not absorbed in the small intestine and, therefore, move down to become fermented in the colon, have drawn attention. These constitute a group of carbohydrates that have been collectively referred to as dietary fibre. Some of these carbohydrates are of particular interest to the food industry for the purpose of developing "functional foods", i.e. foods that are able to exert positive health effects. Prebiotics, for example, are one such type of food, because their non-digestible oligosaccharides stimulate the growth of bifidobacteria in the colon. These bacteria are naturally occurring, and their presence in increased quantities is thought to be beneficial for health (FAO/WHO, 1998). Bifidobacteria appear to protect the colon from colonization by pathogenic species.

## OBESITY

Interest in carbohydrates also stems from the recent worldwide concern about the continuously increasing rates of obesity in adults, and now in children as well (WHO, 1998). Obesity is rising in places where sedentary lifestyles are adopted. Although obesity as a significant phenomenon has usually been associated with developed countries, it is now also on the increase in developing countries. Some of the developing countries are seeing rising rates of obesity at the same time as they are experiencing food insecurity.

There are many hypotheses about obesity, but unfortunately there are no scientifically satisfactory explanations of the

## BOX 1
### RECOMMENDATIONS OF THE FAO/WHO EXPERT CONSULTATION ON CARBOHYDRATES IN HUMAN NUTRITION

The following recommendations are derived from the Consultation discussions and resulting conclusions detailed in the report. Specific recommendations are grouped under the appropriate report headings.

**The role of carbohydrates in nutrition**

1. That the terminology used to describe dietary carbohydrate be standardized with carbohydrates classified primarily by molecular size (degree of polymerization or DP) into sugars (DP 1-2), oligosaccharides (DP 3-9) and polysaccharides (DP 10+). Further subdivision can be made on the basis of monosaccharide composition. Nutritional groupings can then be made on the basis of physiological properties.
2. That the concept of glycaemic carbohydrate, meaning "providing carbohydrate for metabolism", be adopted.
3. Against the use of the terms "extrinsic" and "intrinsic sugars", "complex carbohydrate" and "available" and "unavailable carbohydrate".
4. That food laboratories measure total carbohydrate in the diet as the sum of the individual carbohydrates and not "by difference".
5. That the use of the term "dietary fibre" should always be qualified by a statement itemizing those carbohydrates and other substances intended for inclusion. Dietary fibre is a nutritional concept, not an exact description of a component of the diet.
6. That the use of the terms "soluble" and "insoluble dietary fibre" be gradually phased out. The Consultation recognized that these terms are currently used, but does not consider them a useful division, either analytically or physiologically
7. That the analysis and labelling of dietary carbohydrate, for whatever purpose, be based on the chemical divisions recommended. Additional groupings such as polyols, resistant starch, non-digestible oligosaccharides and dietary fibre can be used, provided the included components are clearly defined.
8. That the energy value of all carbohydrate in the diet be reassessed using modern nutritional and other techniques. However, for carbohydrates that reach the colon, the Consultation recommends that the energy value be set at 2 kcal/g (8 kJ/g) for nutritional and labelling purposes.
9. That the continued production and consumption of root crops and pulses be encouraged to ensure the adequacy and diversity of the supply of carbohydrate.
10. That the continued consumption of traditional foods rich in carbohydrate should be encouraged where populations are in transition from a subsistence rural economy to more prosperous urban lifestyles. Processed foods are likely to be a substantial part of the diet and processing can be used to optimize nutritional properties.

**The role of carbohydrates in the maintenance of health**

11. That the many health benefits of dietary carbohydrates should be recognized and promoted. Carbohydrate foods provide more than energy alone.
12. An optimum diet of at least 55 percent of total energy from a variety of carbohydrate sources for all ages, except for children under two years. Fat should not be specifically restricted below the age of two years. The optimum diet should be introduced gradually beginning at two years of age.
13. That energy balance be maintained by consuming a diet containing at least 55 percent total energy from carbohydrate from various sources, and engaging in regular physical activity.
14. Against consuming carbohydrate levels above the optimum, including carbohydrate-containing beverages, for purposes of recreational physical activity. Higher carbohydrate intakes are only needed for long-term extreme endurance physical activities.
15. That, as a general rule, a nutrient-dense, high-carbohydrate diet be considered optimal for the elderly, but that individualization is recommended because their specific nutritional needs are complex.

**Dietary carbohydrate and disease**

16. That a wide range of carbohydrate-containing foods be consumed so that the diet is sufficient in essential nutrients as well as total energy, especially when carbohydrate intake is high.
17. That the bulk of carbohydrate-containing foods consumed be those rich in non-starch polysaccharides and with a low glycaemic index. Appropriately processed cereals, vegetables, legumes and fruits are particularly good food choices.
18. That excess energy intake in any form will cause body fat accumulation, so that excess consumption of low-fat foods, while not as obesity-producing as excess consumption of high-fat products, will lead to obesity if energy expenditure is not increased. Excessive intakes of sugars, which compromise micronutrient density, should be avoided. There is no evidence of a direct involvement of sucrose, other sugars and starch in the etiology of lifestyle-related diseases.
19. That national governments provide populations in transition from traditional diets to those characteristic of developed countries with dietary recommendations to ensure nutritional adequacy and retention of an appropriate balance of macronutrients.

**The role of the glycaemic index in food choice**

20. That, for healthful food choices, both the chemical composition and physiological effects of food carbohydrates be considered, because the chemical nature of the carbohydrates in foods does not completely describe their physiological effects.
21. That, in making food choices, the glycaemic index be used as a useful indicator of the impact of foods on the integrated response of blood glucose. Clinical application includes diabetes and impaired glucose tolerance. It is recommended that the glycaemic index be used to compare foods of similar composition within food groups.
22. That published glycaemic response data be supplemented where possible with tests of local foods as normally prepared, because of the important effects that food variety and cooking can have on glycaemic responses.

*The major dietary carbohydrates*

| Class (DP)[1] | Subgroup | Components |
|---|---|---|
| Sugars (1-2) | Monosaccharides | Glucose, galactose, fructose |
| | Disaccharides | Sucrose, lactose, trehalose |
| | Polyols | Sorbitol, mannitol |
| Oligosaccharides (3-9) | Malto-oligosaccharides | Maltodextrins |
| | Other oligosaccharides | Raffinose, stachyose, fructo-oligosaccharides |
| Polysaccharides (>9) | Starch | Amylose, amylopectin, modified starches |
| | Non-starch polysaccharides | Cellulose, hemicellulose, pectins, hydrocolloids |

[1] DP = degree of polymerization.

phenomenon. Approaches to the prevention of obesity have varied over the years, but a consensus appears to be emerging on the importance of increasing carbohydrate consumption (in replacement of fat) as a sound strategy. Among other things, this is based on the logic that high-carbohydrate foods are less energy-dense than high-fat foods, since carbohydrate provides only 4 kcal per gram compared with 9 kcal per gram for fat. The implication is that, based on an equal weight of food eaten, a high-carbohydrate food contributes less food energy than a high-fat one, so there is less risk of overeating. However, this is only one facet of a complex process. The role of the diet's macronutrient composition in weight management has been reviewed recently (Rolls and Hill, 1998), and the conclusions lean towards support for higher carbohydrate intakes (thus, reduced fat intake), coupled with lower overall energy intake, as a sound dietary approach to weight loss and maintenance. The FAO/WHO report recommended the consumption of at least 55 percent of energy from a variety of carbohydrate sources (see Box 1, recommendations 12, 13 and 15, and Box 2).

### Glycaemic index

A key index that has become accepted as an indicator of the ability of carbohydrate to prevent diseases of lifestyle and help to reduce the incidence of obesity is the glycaemic index (GI). This measures the glycaemic response (an indication of the rate at which the blood glucose level rises, and how it is sustained over time) after ingestion of carbohydrate foods. There is some evidence that the GI is relevant for sports nutrition (and this notion can be extended to any sustained physical effort, which is a frequent condition of work in developing countries) and also for appetite regulation (FAO/WHO, 1998), with lower GI foods being the better choice in both cases. An important consideration is that GI values can also be determined for mixed meals and whole diets. The expert consultation report makes specific recommendations regarding the GI in recommendations 21 and 22 (see Box 1). In addition, the report of the consultation provides a table of the glycaemic index of selected foods in its background information (FAO/WHO 1998: Table 8).

The above offers only a small opening into the complex issue of addressing and preventing obesity. Its aim is to draw attention to the important place that carbohydrates are gaining in the search for solutions to the problem of obesity, but carbohydrate foods have importance far beyond their potential for preventing obesity or providing energy.

### OTHER BENEFITS

The major providers of food carbohydrates are cereals, representing about 50 percent of all the carbohydrates consumed worldwide. Sugar crops come second, followed by root crops, fruits, vegetables, pulses and milk products. With

## BOX 2
### CARBOHYDRATES AND OBESITY

Among the general public, obesity is a great focus of interest for aesthetic reasons. It is also a focus of concern among public health authorities because it is an independent factor of risk for diseases of lifestyle. Obese individuals are at a high risk of contracting non-insulin-dependent diabetes melitus (NIDDM), cardiovascular disease, disorders of the gastrointestinal tract and some types of cancer (Jung, 1997; FAO/WHO 1998). Therefore, the most promising approach to reducing the incidence of these lifestyle diseases is to reduce the incidence of obesity. On an individual basis, a key strategy in seeking to improve health and prevent non-communicable disease conditions related to dietary lifestyle is to encourage the prevention of excess weight gain leading to obesity or, if obesity is already present, and particularly if it is of the type that is centrally distributed in the body, to embark on a programme to lose weight permanently. As too many people already know, this is easier said than done, but it seems that, from a dietary point of view, increasing the consumption of high-carbohydrate foods, in replacement of high-fat foods, may be a good starting point. The next question relates to whether some carbohydrate foods are more efficient than others at achieving this end. This, in effect, is a question about satiety.

A key area of research in the hunt for ways of preventing excess weight gain is the attempt to find out what brings about satiation and satiety (see definitions below). This has led to studies of diets where the proportions of carbohydrate and fat are manipulated to provide high-carbohydrate or high-fat meals, and their respective impacts on energy balance are examined. Losing weight is a question of ingesting less energy than that which is expended, and this can only be achieved by a lower energy intake, an increased energy expenditure through increased physical activity, or both. It should be emphasized that this other side of the energy equation (energy expenditure) is equally important.

Carbohydrate foods seem to offer a particularly good choice on the energy intake side. In reviewing the subject, Jebb (1998) presents convincing arguments for increasing the intake of carbohydrate foods. Holt *et al.* (1999) reported recently on the effect of high-carbohydrate versus high-fat breakfasts on feelings of fullness and subsequent food intake, and have thus contributed to the evidence that shows that the portion size (the weight and volume of food) and the energy density (kcal/g) of meals are among the strong determinants of the satiating powers of diets, when energy levels ingested are equal. Foods that are high in carbohydrate, particularly when they are high in dietary fibre, had the most impact on reducing hunger and would, therefore, be expected to be those most helpful in reducing energy intake. By contrast, high-fat meals produced low fullness ratings and led to a faster onset of subsequent eating. In their review of the literature, Holt *et al.* cited other work that has shown that subjects tend to eat a constant weight of food, regardless of dietary composition. It could therefore be expected that meals with a lower energy density will have a better chance of preventing excess energy intake. But this does not constitute the magic formula that everyone looks for, and the expert report accordingly makes a recommendation of caution (Box 1, recommendation 18). It should be remembered that a calorie is a calorie, no matter how it is provided.

*Definitions of terminology*

**appetite**: the desire to eat, independent of the body's energy situation;
**hunger**: the sensation that arises when metabolic signals indicate the need to provide the body with food energy;
**satiation**: the process that leads to the end of an eating occasion;
**satiety**: the length of time before another meal is desired.

such a wide representation of food groups among carbohydrate foods, it is not surprising that the experts felt it was necessary to emphasize that carbohydrate foods provide more than energy alone (Box 1, recommendation 11). Although high-carbohydrate foods provide the full range of vitamin and mineral nutrients, some are also particularly rich in phytochemicals, many of which are antioxidants. There is increasing evidence of the role of such substances in the protection of health. ◆

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## Summary/Résumé/Resumen


**Carbohydrates in human nutrition**

FAO and the World Health Organization convene expert consultations on nutrition to ensure that the agencies' scientific knowledge is up to date and to provide advice to member countries. The Expert Consultation on Carbohydrates in Human Nutrition was held in April 1997. In this article, the full set of recommendations made by the experts is provided. Aspects of the experts' report are highlighted, such as the importance of analytical methodologies in stimulating research on carbohydrates, recommended ways of classifying carbohydrates to facilitate food labelling, the interest of the food industry in functional foods, theories about the role of carbohydrates in controlling obesity, the glycaemic index, and some of the contributions carbohydrates make in preventing illness and protecting health.

**Le rôle des glucides dans la nutrition humaine**

La FAO et l'Organisation mondiale de la santé tiennent des consultations d'experts en matière de nutrition afin de s'assurer que les connaissances scientifiques des différentes institutions sont à jour, et de fournir des conseils aux pays membres. C'est dans ce contexte que s'est tenue, en avril 1997, la Consultation d'experts sur le rôle des glucides dans la nutrition humaine. Le présent article brosse un tableau complet des recommandations émanant des experts, tout en soulignant certains aspects de leur rapport, tels que l'importance des démarches analytiques pour encourager les recherches sur les glucides, les méthodes préconisées pour la classification des glucides afin de faciliter l'étiquetage des aliments, l'intérêt de l'industrie alimentaire pour les aliments fonctionnels, les théories concernant le rôle des glucides dans la lutte contre l'obésité, l'indice de glycémie, de même que certains aspects du rôle des glucides dans la prévention des maladies et la protection de la santé.

**Los carbohidratos en la nutrición humana**

La FAO y la Organización Mundial de la Salud (OMS) convocan consultas de expertos en nutrición para cerciorarse de que el conocimiento científico de las organizaciones esté actualizado, y para suministrar asesoramiento a los Estados Miembros. La Consulta de Expertos sobre los Carbohidratos en la Nutrición Humana se celebró en abril de 1997. En el presente artículo se han incluido todas las recomendaciones formuladas por los expertos. También se ponen de relieve algunos aspectos del informe de los expertos tales como la importancia de los análisis para estimular la investigación sobre los carbohidratos, los métodos recomendados para clasificar los carbohidratos a fin de facilitar el etiquetado de alimentos, el interés de la industria alimentaria en los alimentos funcionales, teorías sobre la función de los carbohidratos en el control de la obesidad, el índice de glicemia, y algunas contribuciones de los carbohidratos en lo que se refiere a la prevención de enfermedades y la protección de la salud. ♦