

## MAKE STARCHY FOODS THE BASIS OF MOST MEALS

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The scientific evidence for the guideline, 'make starchy foods the basis of most meals' is reviewed. Worldwide, but especially in developing countries, starchy or high-carbohydrate foods such as cereals, grains and some root vegetables, are the main sources of dietary energy and valuable sources of micronutrients and dietary fibre when they are eaten in minimally processed forms. These foods also contribute protein to the diet.

Recent research has shown that foods rich in carbohydrates in the form of starch, resistant starch, sugars and non-starch polysaccharides or dietary fibre, influence health and prevent chronic diseases by various effects and mechanisms. These include direct effects on digestion, absorption, fermentation and metabolism; indirect effects by providing micronutrients and phytochemicals; and replacement effects, mainly of fat and animal protein.

There is convincing evidence that through these mechanisms high-carbohydrate diets lower risk of several chronic diseases such as obesity, non-insulin-dependent diabetes mellitus, cardiovascular disease, cancer and other gastro-intestinal diseases. Available data indicate that especially white, coloured and Indian South Africans could benefit by increasing intakes of cereals and grains, and that all South Africans should eat more of their cereals and grains in an unprocessed or minimally processed form. The pending fortification of maize meal and bread flour with micronutrients should increase the contribution of starchy foods to micronutrient intakes. It is concluded that available evidence supports this guideline. The guideline is furthermore practical, culturally sensitive, affordable, and sustainable.

The guideline, 'make starchy foods the basis of most meals', is aimed at 'optimum' intakes of cereals and grains such as maize, wheat, sorghum, oats and rice in the form of porridges, breads, pastas, rice, samp, maize rice, breakfast cereals and other products. The guideline advises that in planning of meals, the starchy food should be the central or main food, and the rest of the meal planned around this food. The underlying nutritional objective is to promote an increased intake of

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carbohydrate-rich foods in those people who have low intakes, and to maintain optimal intakes among those currently eating high-carbohydrate diets. Other carbohydrate-containing foods are root crops, sugar crops, pulses (legumes), vegetables, fruit and milk products. The recommendation to make starchy foods the basis of most meals should be accompanied by advice to choose unrefined or minimally processed cereals and grains where possible, and to concentrate on fortified cereals and grains when available.

There are several ways in which high intakes of cereals and grains will beneficially influence total nutrient balance and health. Direct effects of an increased starch intake on the physiology of the intestinal tract and metabolism can be expected. Many associated substances in these foods such as cereal fibre, oligosaccharides, phytoestrogens, phytosterols, flavonoids, terpenes and isothiocyanates are now known to influence health beneficially. Carbohydrate-containing foods are also excellent sources of several vitamins and minerals, and some, if eaten in sufficient quantities, can make substantial contributions to protein intake. Although some of the substances such as phytates in unrefined cereals and grains may inhibit absorption of these micronutrients, unrefined cereals and grains are accepted as good sources of micronutrients.

Increased intakes of starchy foods can also replace some animal-derived and fatty foods in the diet, leading to a decreased fat and animal protein intake. This, together with increased intakes of fibre, resistant starch and associated plant substances will decrease the risk of many overnutrition-related chronic diseases such as coronary heart disease (CHD), stroke, non-insulin-dependent diabetes mellitus (NIDDM), and some forms of cancer. The contribution of micronutrients to the diet by unrefined and fortified cereals and grains will help to prevent micronutrient undernutrition. Starchy foods therefore have direct, indirect or 'replacement' effects on nutritional status and health.

The scientific evidence to support these statements on the beneficial effects of starchy foods and/or high-carbohydrate diets, which form the background and motivation for this guideline, will be reviewed briefly.

### DIETARY CARBOHYDRATES

The role of carbohydrates in human nutrition, maintenance of health and prevention of disease, has recently been updated and reviewed by a joint Food and Agricultural Organisation/World Health Organisation (FAO/WHO) Expert Consultation.<sup>1</sup> This consultation group defined carbohydrates as the polyhydroxy aldehydes, ketones, alcohols, acids, their simple derivatives and their polymers, with linkages of the acetal type.

A simplified classification of dietary carbohydrates is given in Table I, indicating that in addition to the amylose and

**Table I. Simplified classification of dietary carbohydrates\***

Class	Sub-group	Components	Remarks
Sugars 1 - 2 units polymerised †	Monosaccharides	Glucose, galactose, fructose Sucrose, lactose, trehalose	The term 'sugars' describes mono- and disaccharides; sugar is synonymous with sucrose; 'milk sugar' is lactose
	Disaccharides	Sorbitol, mannitol	
	Polyols		
Oligosaccharides 3 - 9 units polymerised	Malto-oligosaccharides	Maltodextrins	Some oligosaccharides are not digested to glucose and other monosaccharides, and could be classified on a physiological basis as dietary fibre or 'unavailable' carbohydrate
	Other oligosaccharides	Raffinose, stachyose, fructo-oligosaccharides	
Polysaccharides > 9 units polymerised	Starch ( $\alpha$ -glucans)	Amylose, amylopectin, modified starches; rapidly digestible starch; resistant starch ‡	The amylose/amylopectin ratio in starch can be modified by plant breeding; starch can also be physically or chemically modified to change viscosity, mouth feel, appearance, texture, etc. as in many convenience products Group of carbohydrate substances not digested to glucose but fermented in large gut
	Non-starch polysaccharides (also known as dietary fibre)	Cellulose, hemicellulose, pectins, beta-glucans, gums, mucilages, hydrocolloids	

\* Adapted from the Joint FAO/WHO Expert Consultation.<sup>1</sup>

† Unit refers to the basic monosaccharide (usually a 6 carbon molecule) and polymerised to the connection of the monosaccharide units by glycoside bonds.

‡ Resistant starch refers to the fraction of starch that resists digestion in the small intestine but which is fermented in the colon.

amylopectin fractions of starch, modified starches and different degrees or types of resistant starch are now recognised as important dietary carbohydrates. Carbohydrates are the most important source of food energy in the world, providing 40 - 80% of total food energy intake, influenced by geographical location, cultural considerations and economic status.<sup>1</sup> In addition to being the main provider of dietary energy, carbohydrates function as sweeteners, making diets more palatable, and influence satiety mechanisms in the control of food intake. The dietary fibre components moderate digestion and absorption of other nutrients in the small bowel and together with undigested starch, form the major substrate for microbial fermentation in the large bowel, influencing bowel habits, metabolism and health.<sup>1</sup>

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The nutrient goals for dietary carbohydrate intake<sup>1</sup> are based on three accepted scientific principles: (i) the minimum amount of carbohydrate needed in the human diet by adults to prevent ketosis is 50 g/day; (ii) at least 55% of total energy should be provided by a variety of carbohydrate sources to protect against chronic diseases (leaving a maximum of about 30% for fat and 15% for protein) — if more than 75% of dietary energy is provided by carbohydrate, intakes of fat, protein and some

micronutrients will be compromised; and (iii) moderate intake of sugar and sugar-rich foods can also provide for a palatable and nutritious diet.

### Functions of dietary carbohydrate

As a group and also individually, the different dietary carbohydrates have a wide range of physiological effects that are important for maintenance of health and prevention of disease. These effects have been reviewed by the FAO/WHO Consultation,<sup>1</sup> and are summarised in Table II. They represent the direct effects of carbohydrates. As mentioned, carbohydrate-containing foods also provide other nutrients and phytochemicals (indirect effects) and will influence health and prevent disease by replacing fat in the diet. Therefore, a wide range and variety of carbohydrate-containing foods should be consumed to ensure adequate intake of these other substances.

### Carbohydrate intakes of South Africans

The mean daily carbohydrate intakes of adult South Africans aged 25 - 65 years are summarised in Table III. Although there are gaps in available data, notably on habitual intakes of

**Table II. Summary of physiological effects of dietary carbohydrate\***

	Effect	Remarks
1.	Provision of energy	Starch digested to glucose and disaccharides has an energy value of 17 kJ/g; glucose has 15.7 g/kJ and undigested but fermentable CHO (starch and fibre) an estimated mean of 8 kJ/g.
2.	Satiety and gastric emptying	CHO suspected to have a positive role but more research, also on satiety index, is needed.
3.	Glucose and insulin homeostasis	The rates of digestion and absorption of dietary CHO influence blood glucose, insulin secretion and cellular glucose uptake. CHO intakes influence insulin sensitivity/resistance.
4.	Protein glycosylation	Non-enzymatic glycosylation of proteins is influenced by blood concentration of glucose and fructose and the half-life of protein. Low glycaemic index CHOs have smaller effects.
5.	Serum lipids and bile acids	High CHO diets which are also high in soluble dietary fibre have lowering effects on TC, LDLC, TG and do not decrease HDLC. Fibre decreases serum lipids by bile acid adsorption, and through fermentation products (SCFA) effects on metabolism.
6.	Fermentation of: undigested resistant starch, dietary fibre, oligosaccharides, unabsorbed lactose	CHOs that escape digestion in small bowel are fermented to hydrogen, methane, SCFA, CO <sub>2</sub> ; this stimulates microbial growth. (Lactose 'malabsorption' is not a pathological state, unless secondary to mucosal disease.)
7.	Bowel habits	Dietary fibre (and to a limited extent, resistant starch) affects laxation, depending on amounts, fermentation and water-holding capacity. Cereal fibre is the most laxative.
8.	Growth of microflora (pre-biotics are foods that stimulate growth of gut bacteria, protecting the host from invasion by pathogenic species)	Fermentable CHOs stimulate bacterial growth in the large gut, and increase biomass and nitrogen excretion, depending on the type of CHO, rate of breakdown, and transit time. Fructo-oligosaccharides stimulate growth of bifidobacteria.
9.	Physical activity	CHOs play an important role in exercise and can increase performance during endurance events.
10.	Behaviour	Consumption of breakfast by children and maintaining blood glucose levels are associated with improved cognitive performance. There is no evidence that sucrose negatively affects the behaviour of children.

\* Adapted from the FAO/WHO Consultation.<sup>1</sup>

CHOs = carbohydrates; SCFA = short chain fatty acids (acetate, propionate and butyrate); TC = total serum cholesterol; LDLC = serum low-density lipoprotein cholesterol; HDLC = serum high-density lipoprotein cholesterol; and TG = serum triglycerides.

Indians and 24-hour recall data among rural black men, from Table III it is clear that the black South African population still has the highest carbohydrate intake, followed by coloured South Africans. Indian South Africans seem to have even lower intakes than the white population.

To provide at least 55% of the energy of an 8 000 kJ diet (for women) and a 10 000 kJ diet (for men), at least 259 g and 325 g carbohydrate per day should be consumed respectively. When habitual and 24-hour recall intakes of South African men and women are compared (Table III) it seems that black and coloured South Africans generally take in adequate amounts of carbohydrate, while whites and Indians should be encouraged to consume more carbohydrate in relation to other macronutrients. The generally low intake of fibre in all groups emphasises the need to encourage consumption of unrefined or minimally processed carbohydrate-rich foods in all groups. The low, and often deficient intake of several micronutrients,

especially by black and coloured people,<sup>2</sup> supports the recommendation that fortified cereals and grains should be eaten more often.

#### EVIDENCE THAT CARBOHYDRATE FOODS INFLUENCE HEALTH AND PREVENT DISEASE

There are many studies available to evaluate if and how carbohydrates or carbohydrate-containing foods influence health. Several approaches can be followed to group and evaluate these studies. A conceptual framework to categorise studies and their outcomes is given in Fig. 1. The figure indicates how epidemiological studies provide data on the relationships between the intake of specific foods, food groups or nutrients and health, risk of disease or specific diseases. Intervention or clinical studies provide data on how effectively or efficiently a particular dietary (food or nutrient) change may

Table III. Mean ( $\pm$  standard deviation (SD)) daily carbohydrate intakes in grams for adult South Africans aged 25 - 65 years<sup>2,3</sup>

Population group	Men				Women			
	Total*	Starch <sup>†</sup>	Fibre <sup>‡</sup>	Sugar <sup>§</sup>	Total*	Starch <sup>†</sup>	Fibre <sup>‡</sup>	Sugar <sup>§</sup>
Urban blacks								
24-h <sup>¶</sup>	282 (112)	211.7	19.5 (13.5)	50.8 (47.8)	222 (89)	161.6	14.6 (8.8)	45.8 (37.9)
Habitual <sup>  </sup>	417 (188)		29.8 (20.5)	123.0 (87.3)	298 (150)		18.6 (9.4)	94.2 (67.6)
Non-urban blacks								
24-h	-	-	-	-	409 (122)	311.0	37.0 16.0	61.0 36.0
Habitual	377 (132)		19.4 (8.8)	33.2 (37.1)	297 (87)	25.1	25.1 (9.2)	44.6 (36.4)
Whites								
24-h	280 (122)	172.2	18.5 (10.6)	89.3 (61.4)	183 (86)	117.5	13.7 (7.8)	51.8 (40.3)
Habitual	324 (129)		26.7 (18.7)	93.6 (60.4)	230 (61)		26.0 (9.4)	51.1 (36.4)
Coloureds								
24-h	240 (106)	147.9	13.7 (8.8)	78.4 (54.1)	177 (79)	103.5	10.7 (6.4)	62.8 (41.9)
Habitual	453 (155)		16.6 (7.3)	155.0 (59.0)	362 (111)		13.7 (6.4)	126.0 (59.6)
Indians								
24-h	231 (88)	141.3	16.9 (8.65)	72.8 (46.2)	164 (62)	102.5	13.1 (6.6)	48.4 (33.3)
Habitual							-	-

\* = Total carbohydrates, determined by difference method as given in the South African Food Tables.<sup>2,3</sup><sup>†</sup> = Starch calculated as total carbohydrate — (fibre + sugar).<sup>‡</sup> = Total dietary fibre.<sup>§</sup> = Added sugar (sucrose).<sup>¶</sup> 24-h: Intakes measured using the 24-hour recall method.<sup>||</sup> Habitual: Intakes measured using a food frequency questionnaire, diet history or weighed records.

influence human physiology and biochemistry and therefore nutritional status and health. *In vivo* or *in vitro* experimental studies provide information on possible mechanisms of action and evidence to support observations from epidemiological and clinical studies.

Using this framework, some recent studies<sup>5-11,14-28</sup> in which particular effects of dietary carbohydrate and/or cereal foods have been examined, will be discussed.

### Obesity

Because carbohydrate, and especially starch, is the main contributor to dietary energy, there are often misconceptions about its role in maintaining healthy body weight and in obesity. A recent WHO Consultation on Obesity<sup>4</sup> concluded that the bulk of the evidence suggests that carbohydrate and protein balances, but not fat balance, are well regulated; that weight changes are primarily caused by disruption of fat balance; that those macronutrients with a low storage capacity within the body (alcohol, protein and carbohydrate — but not fat) are preferentially oxidised when intakes exceed requirements; and that excess carbohydrate can also be converted to fat, but that human subjects do not use this

metabolic pathway to any appreciable extent unless large excesses of a low-fat, high-carbohydrate diet are consumed.

However, when carbohydrate is oxidised less fatty acid oxidation is required. So, dietary fat is stored and endogenous fat retained.<sup>4,5</sup> About 60% - 80% of the excess energy may be stored on carbohydrate overfeeding, compared with 96% on fat overfeeding.<sup>4</sup> Furthermore, fat is much more energy-dense than carbohydrate, containing 38 kJ/g compared with 17 kJ/g. This explains why carbohydrate foods should not generally be regarded as 'fattening'. However, as has been shown for rural black women,<sup>6</sup> it is possible to become obese on low-fat, high-carbohydrate diets, especially if these diets are accompanied by low levels of physical activity.

Jenkins *et al.*<sup>7</sup> recently showed in an intervention study that decreased intakes of carbohydrate correlated with a fall in leptin concentration during weight loss. These authors speculated that leptin defends the body's carbohydrate stores and that leptin is involved in the satiating effect of carbohydrate. Their results suggest that dietary interventions that maintain leptin levels during weight loss may lead to improved weight loss. This supports the recommendation that diets should contain adequate amounts of carbohydrate and limited amounts of fat.

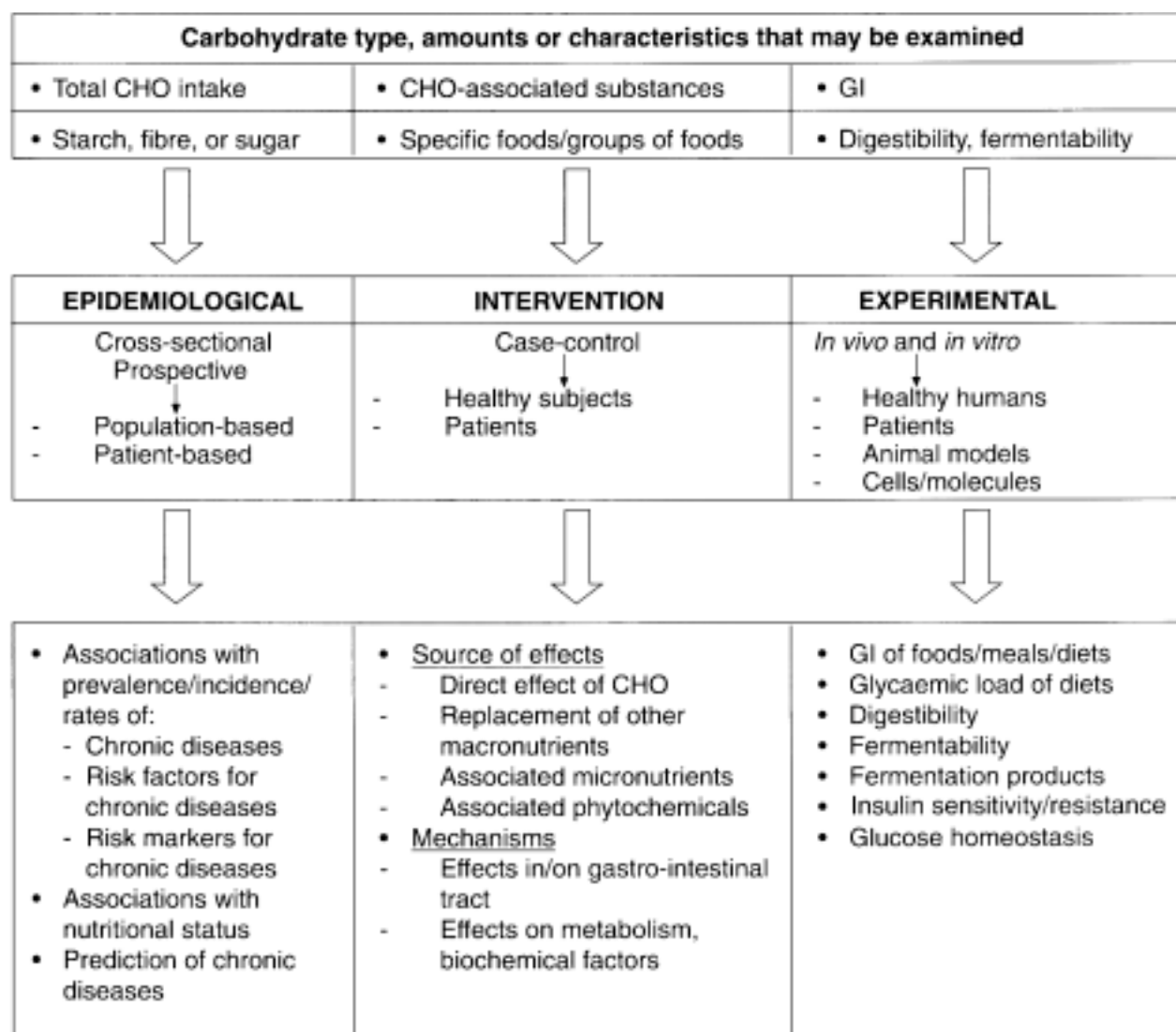


Fig. 1. A conceptual framework of different categories of studies that should be considered to evaluate the relationship between dietary carbohydrates and health (CHO = carbohydrate; GI = glycaemic index).

### Non-insulin dependent diabetes mellitus (NIDDM)

The FAO/WHO Consultation on Carbohydrates<sup>6</sup> concluded that NIDDM is a multifactorial disease with a strong genetic basis. However, available evidence suggests that carbohydrate-containing foods rich in non-starch polysaccharides (dietary fibre) and with a low glycaemic index (GI) protect against the development of NIDDM, the effect being independent of body mass index. High intakes of a wide range of carbohydrate foods are also accepted for the nutritional management of people who have already developed NIDDM.

Sucrose and other sugars have not been directly implicated in the aetiology of diabetes,<sup>7</sup> and most recommendations permit 30 - 50 g per day for diabetic subjects, provided that this is consumed within the context of the total energy allowance, that it does not replace nutrient-dense and high-fibre foods, and that it is incorporated into mixed meals.<sup>6</sup> A recent clinical

trial involving NIDDM patients<sup>8</sup> indicated that a very high-fibre diet, containing 50 g of fibre of which 25 g were soluble and 25 g insoluble fibre, improved glycaemic control, decreased hyperinsulinaemia and lowered plasma lipid concentrations. The overall decrease in plasma glucose concentrations was similar to that typically achieved with oral hypoglycaemic drugs.

Wolever<sup>9</sup> reviewed the evidence that low GI carbohydrate-containing foods decrease risk of NIDDM, and increase insulin sensitivity. There are indications that undigested, but fermented starch may also influence the haemostatic system, which may be beneficial for diabetic patients. Ceriello and co-workers<sup>10</sup> recently showed that the activation of the haemostatic system by hyperglycaemia in diabetic subjects could be decreased by acarbose, an enzyme that inhibits carbohydrate (starch) digestion in the small bowel. In this

clinical trial acarbose feeding resulted in decreased post-prandial hyperglycaemia and a decrease in plasma prothrombin fragment 1 + 2 as well as plasma D-dimer. The latter two are indicators of coagulation activation. The undigested starch is fermented to short chain fatty acids (SCFAs) in the large bowel. The formed butyrate is metabolised by the colonic epithelial cells, propionate by the liver and acetate by muscle cells.<sup>11</sup> It is generally accepted that many of the beneficial effects of starch and fibre can be attributed to the production of these SCFAs.

From the above, it seems that consumption of high-carbohydrate diets which provide carbohydrate substrates for large bowel fermentation, have several benefits for NIDDM patients and probably also for the general population.

### Cardiovascular disease

Despite recent decreases in prevalence, CHD remains a major killer in white, Indian and coloured South Africans, while stroke is suspected to be a major problem in the black population.<sup>12</sup> CHD and stroke are both multifactorial diseases in which complex interactions between genetic predisposition and environmental factors, including diet, influence the atherosclerotic and thrombotic process underlying the clinical manifestations of these diseases.

After an extensive review of available evidence, the FAO/WHO Consultation<sup>1</sup> concluded that prospective studies have shown that cereal foods rich in dietary fibre are protective against CHD. Increased intakes of antioxidant nutrients (mainly from fruits and vegetables) and replacement of fatty foods by foods rich in carbohydrate such as cereals should form the cornerstone of dietary advice to protect against CHD.<sup>1</sup> Specific dietary fibre components such as  $\beta$ -glucans found in oats, have been shown to lower serum total and low-density lipoprotein (LDL) cholesterol levels significantly. These foods are useful in management of hypercholesterolaemia, but their role in prevention of CHD remains to be established.<sup>1</sup>

Another possible mechanism by which carbohydrate foods may protect against CHD is through effects on high-density lipoprotein (HDL) cholesterol. Frost *et al.*<sup>13</sup> recently re-analysed data from the 1986 - 1987 Survey of British Adults and found a negative correlation between serum HDL cholesterol levels and the GI of the diet. The GI of the total diet was a stronger predictor of the HDL cholesterol level than dietary fat. These results confirm other observations of an association between low GI foods and high HDL concentrations<sup>9</sup> and suggest a role for carbohydrate foods in lowering CHD risk.

Strong evidence that whole-grain cereal foods are protective against CHD came from the prospective Nurses' Health Study<sup>14</sup> in which 761 cases of CHD (208 fatal, 553 non-fatal) were documented during 729 472 person years. Increased intakes of whole (unrefined) grains were associated with a decreased risk of CHD (adjusted for age and smoking). The strongest effect

was seen in never-smokers. The authors mentioned that the lower risk of CHD was not fully explained by the grain's contribution to fibre, folate, vitamin B<sub>6</sub> or vitamin E intakes, and speculated that additional protective mechanisms were operative.

The major risk factors for stroke are hypertension and increased plasma fibrinogen, both being prevalent in the black population.<sup>15</sup> Less is known about dietary effects on these two risk factors, but the FAO/WHO Consultation advised that since plant foods are good sources of potassium, increased intake of all plant foods may reduce the sodium-potassium ratio and therefore the risk of hypertension.<sup>1</sup>

### Cancer

Cancer is a disease associated with well-recognised genetic abnormalities, but diet is regarded as an important risk factor for colorectal, breast and uterine cancers.<sup>1</sup> Meat and fat intakes are associated with increased risk of colorectal cancer, and total energy (leading to obesity) with breast and uterine cancer.<sup>1</sup> Cereal foods, fruit and vegetables are generally regarded as being protective.<sup>1</sup> However, in a recent review, Hill<sup>6</sup> concluded that it is especially cereals and vegetables that protect against colorectal cancer, while fruit seems to be neutral.

There seems to be agreement in the literature<sup>16-19</sup> about the mechanisms by which carbohydrate foods may protect against colorectal cancer. These include the formation of butyric acid from the fermentation of undigested resistant starch, oligosaccharides and dietary fibre in the large bowel; the dilution of potential carcinogens by these carbohydrates; the reduction of products of protein fermentation through stimulation of bacterial growth; pH effects; maintenance of the gut mucosal barrier; and effects on bile acid degradation. It is thought that the formation of butyric acid, which arrests cell growth, influences differentiation and 'selects' damaged cells for cell death (apoptosis), is the primary protective mechanism.<sup>1</sup> Resistant starch, found in green bananas, cold cooked starches, and minimally processed wheat and maize,<sup>20,21</sup> is a good source of butyric acid.

Southgate<sup>22</sup> estimated that with a 150 g starch intake, about 15 g will reach the colon, depending on the physical structure of the food. The importance of adequate amounts of undigested carbohydrates reaching the colon is being increasingly recognised — not only for butyric acid production, but also for growth and activity of bacteria to synthesise vitamins, to metabolise bile acids and other steroids, and for laxative properties.<sup>11,21,23</sup>

Other compounds than starch and dietary fibre in unrefined cereals, fruits and vegetables, such as antioxidant micronutrients, phytoestrogens, the phenolic compounds (ferulic and caffeic acid) and the large range of isoprenoids are all thought to protect against various forms of cancer.<sup>17-19</sup>

### Other gastro-intestinal diseases

Dietary fibre, especially from unrefined cereals, and resistant starch intake increase stool weight and prevent (and can be used in treatment of) constipation, haemorrhoids, anal fissures and diverticular disease. Carbohydrates that are not digested in the small intestine but fermented in the large intestine, and therefore facilitate colonisation of bifidobacteria and lactobacilli, reduce the risk of acute infective gastro-intestinal diseases.

### Dental caries

Foods containing sugars and starch are broken down by amylase and bacterial enzymes in the mouth. The produced acid increases caries risk.<sup>1</sup> However, the impact of carbohydrates on caries is dependent on the type of food, frequency of consumption, degree of oral hygiene, fluoride availability, salivary function and genetic factors.

### THE GLYCAEMIC INDEX (GI) OF CARBOHYDRATE FOODS

The beneficial effects of low-GI foods have been mentioned above in the context of preventing chronic diseases. This index is defined<sup>1</sup> as the incremental area under the blood glucose response curve of a 50 g carbohydrate portion of a test food expressed as a percentage of the response to 50 g carbohydrate from a standard food (glucose or white bread) taken by the same subject. The methods for determining and calculating the GI of foods, meals and diets, have been described by the FAO/WHO Consultation.<sup>1</sup>

Carbohydrates that are slowly digested and absorbed have low GIs. Food form, determining accessibility of digestive enzymes, therefore has a pronounced effect on the GI.<sup>24</sup>

There is some concern about standardisation of methods to determine GI in different laboratories, and about intra- and interindividual variations in blood glucose responses. Nevertheless, the GI is accepted as a useful tool in choosing carbohydrate foods for specific purposes, because the same foods are mostly categorised as low, medium or high GI foods using existing methods.<sup>24</sup> However, in applying the GI to choose foods, it should be kept in mind that the GI reflects the acute or immediate response to the carbohydrate in the food, and that other nutrients, notably fat and dietary fibre, will also decrease GI.

Results from the Health Study<sup>25</sup> recently emphasised the possible importance of low GI foods. In this study of an American female population, the total glycaemic load of the diet was positively related to CHD risk in women with a body mass index above 23 kg/m<sup>2</sup>. But the carbohydrates with a high GI were more strongly associated with the increased risk compared with carbohydrates with low GIs when the data were controlled for total energy, protein, fat and carbohydrate. This study underlines that lowering of the GI of the diet by

increasing intakes of unprocessed carbohydrate foods compared with refined products will probably have long-term beneficial health effects. Low GI carbohydrate-containing foods seem to play a role in prevention of chronic diseases, while high GI foods may be the preferred choice in specific circumstances such as restoring glycogen stores after exercise.<sup>26</sup>

### CARBOHYDRATES AND FUNCTIONAL FOODS

Functional foods<sup>27</sup> are foods or food products in which composition and other properties have been changed to have specific functions in the body — usually for improving sensory characteristics, shelf life, nutritional status and prevention of chronic disease.

Starchy foods are particularly suitable for development of functional foods because starch content and properties can be modified using various methods. For example, Hoebler *et al.*<sup>28</sup> have shown that by substituting high amylo-maize starch for a part of the flour in bread, the GI of the bread can be lowered. Amylose is a straight-chain polysaccharide which is slowly digested, while the branched chain of amylopectin allows multiple access points for digestive enzymes.

Therefore, by changing the amylose/amylopectin ratio of starch in food products,<sup>28</sup> or increasing the amount of resistant starch and decreasing rapidly available glucose in foods,<sup>29</sup> the GI of the food and its function in the body can be manipulated. As more of these food products become available in future, dietary recommendations on how to incorporate them in healthy diets will have to be developed.

### PRACTICAL RECOMMENDATIONS

Cereals and grains are the most economic sources of dietary energy and therefore form the staple food of many developing populations. In South Africa, maize has been traditionally used as staple food, and with the addition of legumes, vegetables and small amounts of animal-derived foods, formed the basis of adequate diets in the past. Today, all South Africans can benefit by eating one or more servings of this food group during each meal, preferably in an unrefined form. A wide choice of different cereals and grains and their products such as breads, porridges, pastas, breakfast cereals as well as 'rice' from maize, wheat, rice, sorghum, and rye are available to bring variety in the diet.

### CONCLUDING REMARKS

Because of all the mentioned beneficial effects of carbohydrate foods, and cereals and grains in particular, the dietary guideline 'to make starchy foods the basis of most meals' has a sound scientific base. It is supported by convincing results from epidemiological observations, clinical intervention studies and extensive experimental work on the mechanisms of how

these foods and their carbohydrate constituents influence health and prevent disease. But it is also a practical, affordable and culturally sensitive guideline. South Africa produces sufficient amounts of these foods for its population and starchy foods such as maize, bread and rice are eaten by most South Africans. However, available information suggests that all South Africans will benefit by consuming more unrefined cereals and grains, and many will improve their nutritional status by choosing fortified cereals and grains. With the intended mandatory fortification of maize meal and bread flour in South Africa, this last choice will become increasingly easier.

## References

1. Food and Agricultural Organisation/World Health Organisation. *Carbohydrates in Human Nutrition*. Report of a joint FAO/WHO Expert Consultation, Rome, 14 - 18 April 1997. Rome: FAO, 1998: 1-140.
2. Vorster HH, Oosthuizen W, Jerling JC, Veldman FJ, Burger HM. *The Nutritional Status of South Africans. A Review of the Literature. Narrative and Tables*. Durban: Health Systems Trust, 1997: 1-48, 1-122.
3. Vorster HH. Diet and large bowel cancer. Discussion. In: Shetty PS, McPherson K, eds. *Diet, Nutrition and Chronic Disease. Lessons From Contrasting Worlds*. Chichester, UK: John Wiley and Sons, 1997: 140-145.
4. World Health Organisation Consultation on Obesity. *Obesity: Preventing and Managing the Global Epidemic*. Geneva: WHO, 1998; WHO/NUT/NCD/98.1: 1-276.
5. Graham TE, Adamo KB. Dietary carbohydrate and its effect on metabolism and substrate stores in sedentary and active individuals. *Can J Appl Physiol* 1999; **24**: 393-415.
6. Kruger HS, Venter CS, Vorster HH. The association between measures of obesity in black women in the North West Province, South Africa: the THUSASTUDY. *Br J Nutr* (in press).
7. Jenkins AB, Markovic TP, Fleury A, Campbell LV. Carbohydrate intake and short-term regulation of leptin in humans. *Diabetologia* 1997; **40**: 348-351.
8. Chandalia M, Garg A, Lutjohann D, van Bergmann K, Grundy SM, Brinkley LJ. Beneficial effects of high fiber intake in patients with type 2 diabetes mellitus. *N Engl J Med* 2000; **342**: 1392-1398.
9. Wolever TMS. Dietary carbohydrate and insulin action in humans. *Br J Nutr* 2000; **83**: suppl 1, S97-S102.
10. Ceriello A, Taboga C, Tonutti L, et al. Post-meal coagulation activation in diabetes mellitus: the effect of acarbose. *Diabetologia* 1996; **39**: 469-473.
11. Cummings JH, Macfarlane GT. Role of intestinal bacteria in nutrient metabolism. *Journal of Parenteral and Enteral Nutrition* 1997; **21**: 357-365.
12. Bradshaw D, Bourne DE, Schneider M, Sayed R. Mortality patterns of chronic diseases of lifestyle in South Africa. In: Fourie J, Steyn K, eds. *Chronic Diseases of Lifestyle in South Africa*. Parow: SAMRC, 1995: 5-35.
13. Frost G, Leeds AA, Dore CJ, Madeiros S, Brading S, Dornhorst A. Glycaemic index as a determinant of serum HDL-cholesterol concentration. *Lancet* 1999; **353**: 1045-1048.
14. Liu S, Stampfer MJ, Hu FB, et al. Whole-grain consumption and risk of coronary heart disease: results from the Nurse's Health study. *Am J Clin Nutr* 1999; **70**: 412-419.
15. Vorster HH, Jerling JC, Styen K, et al. Plasma fibrinogen of black South Africans: the BRISK study. *Public Health Nutrition* 1998; **1**: 169-176.
16. Hill MJ. Cereals, cereal fibre and colorectal cancer risk: a review of the epidemiological literature. *Eur J Cancer Prev* 1997; **6**: 219-225.
17. Slavín J, Jacobs D, Marquart L. Whole-grain consumption and chronic disease: protective mechanisms. *Nutr Cancer* 1997; **27**(1): 14-21.
18. Witte JS, Longnecker MP, Bird CL, Lee ER, Frankl HD, Haile RW. Relation of vegetable, fruit and grain consumption to colorectal adenomatous polyps. *Am J Epidemiol* 1996; **144**: 1015-1025.
19. Mo H, Elson CE. Apoptosis and cell-cycle arrest in human and murine tumor cells are initiated by isoprenoids. *J Nutr* 1999; **129**: 804-813.
20. Asp NG. Resistant starch — an update on its physiological effects. *Adv Exp Med Biol* 1997; **427**: 201-210.
21. Cummings JH, Beatty ER, Kingman SM, Bingham SA, Englyst HN. Digestion and physiological properties of resistant starch in the human large bowel. *Br J Nutr* 1996; **75**: 733-747.
22. Southgate DA. How much and what classes of carbohydrate reach the colon. *Eur J Cancer Prev* 1998; **7**: suppl 2, S81-82.
23. Jenkins DJ, Vuksan V, Rao AV, et al. Colonic bacterial activity and serum lipid risk factors for cardiovascular disease. *Metabolism* 1999; **48**: 264-268.
24. Vorster HH, Venter CS, Silvis N. The glycaemic index of foods: a critical evaluation. *SAJ Food Sci Nutr* 1990; **2**(1): 6-9.
25. Liu S, Willet WC, Stampfer MJ, et al. A prospective study of dietary glysemic load, carbohydrate intake, and risk of coronary heart disease in US women. *Am J Clin Nutr* 2000; **71**: 1455-1461.
26. Walton P, Rhodes EC. Glycaemic index and optimal performance. *Sports Med* 1997; **23**: 164-172.
27. American Dietetic Association. Position of the American Dietetic Association: functional foods. *J Am Diet Assoc* 1999; **99**: 1278-1285.
28. Hoebler C, Karinthi A, Chiron H, Champ M, Barry JL. Bioavailability of starch in bread rich in amylose: metabolic responses in healthy subjects and starch structure. *Eur J Clin Nutr* 1999; **53**: 360-366.
29. Englyst HN, Veenstra J, Hudson GJ. Measurement of rapidly available glucose (RAG) in plant foods: a potential *in vitro* predictor of the glycaemic response. *Br J Nutr* 1996; **75**: 327-337.