Carbohydrates

1. Background Information

The nutritional significance of carbohydrates differs depending on the sub-classification (particularly sugars versus polysaccharides, and starch versus non-starch polysaccharides). However, currently, food composition tables (*Standard Tables of Food Composition in Japan 2010*)[(1)] do not list the contents of these carbohydrates in many foods, so it is difficult to measure the dietary intake and supply in Japanese people. Therefore, the DRIs for only (total) carbohydrates and dietary fiber were determined. In addition, alcohol, which is not a carbohydrate but produces energy, and its association with various life-style related diseases (LRDs) is drawing attention; this will be discussed in this chapter.

1-1. Definitions and Classifications

The compositional formula of carbohydrate is $C_n(H_2O)_n$. Carbohydrates can be monosaccharides or polymers; monosaccharides are the minimum constituent unit. They are classified according to their chemical, physical, and physiological characteristics. When classified according to the degree of polymerization, which is a chemical characteristic, carbohydrates are divided into saccharides (1 degree or 2 degrees of polymerization), oligosaccharides (3–9 degrees of polymerization), and polysaccharides (10 or more degrees of polymerization)[(2)]. Saccharides are further divided into monosaccharides and disaccharides. Monosaccharides include glucose, fructose, and galactose; and disaccharides include sucrose, lactose, and maltose. Oligosaccharides are divided into maltooligosaccharides (alpha-glucan), and oligosaccharides containing monosaccharides other than glucose. Polysaccharides are divided into starch and non-starch polysaccharides. The former consists of amylose and amylopectin, while the latter includes cellulose, hemicellulose, and pectin[(2)]. In terms of physiological classification, carbohydrates are classified into carbohydrates that can be digested by human digestive enzymes, and carbohydrates that cannot be digested. The term “dietary fiber” is the result of a classification method focused on physiological characteristics; however, the definition of dietary fiber differs slightly between organizations in and outside Japan[(3)]. If only regular foods are consumed, the majority of dietary fiber consumed is in the form of non-starch polysaccharides.

2. DRIs for Carbohydrates

2-1. Carbohydrates

The main nutritional role of carbohydrates is to supply glucose to tissues that can usually use only glucose as an energy source, such as the brain, nervous tissue, red blood cells, renal tubules, testes, and oxygen-deficient skeletal muscles. The brain accounts for approximately 2% of the total body weight, but is assumed to consume approximately 20% of an individual’s basal metabolic rate[(4)]. If the basal metabolic rate is 1,500 kcal/day, the brain’s energy expenditure is 300 kcal/day, which is equal to 75 g/day of glucose. As explained above,

since tissues other than the brain also use glucose as an energy source, the glucose requirement is estimated to be no less than 100 g/day. In other words, the minimum digestible carbohydrate requirement is assumed to be approximately 100 g/day. However, this does not necessarily mean that this is the minimum amount truly required. This is because the liver performs glucogenesis using the lactic acid and amino acids released from the muscles, and glycerol released from adipose tissue as needed to supply glucose in the blood. Furthermore, individuals other than infants also usually consume a considerably larger amount (> 100 g/day) of carbohydrate. Therefore, there is little sense or value in calculating the estimated requirement on the basis of this amount. Moreover, as will be explained later on, reports stating that carbohydrates are the direct cause of specific adverse health events are not sufficiently supported theoretically and epidemiologically, with the exception of diabetes--a type of LRD. Consequently, no estimated average requirement (EAR) (and recommended dietary allowance [RDA]), tolerable upper intake limit level (UL), or adequate intake (AI) was set for carbohydrates.

The percentage of energy (%E) derived from carbohydrates as a proportion of total energy intake is more often used to consider the relationship between carbohydrates and diabetes than absolute amounts (g/day). This is because carbohydrates are a major source of energy, and both the intake of carbohydrate as an energy source and the direct effect of carbohydrates on adverse health events must be jointly considered. This is discussed in the chapter “Energy Providing Nutrients’ Balance.”

The reference intakes for saccharides was not set at this time due to difficulties in measuring their intake in Japanese people.

2-2. Dietary Fiber

2-2-1. Basic Concept

Many reports describe a correlation between the inadequate intake of dietary fiber and the development of LRDs. It was, therefore, deemed appropriate to set a tentative dietary goal (DG) for the prevention of LRDs.

2-2-2. Preventing the Development and Progression of LRDs

2-2-2-1. Association with LRDs

(1) Association between Dietary Fiber and the Prevention of LRDs Development

A wide range of LRDs have been examined for their association with dietary fiber intake. Many studies have found that dietary fiber intake is negatively correlated with the development of and death from myocardial infarction[5,6], development of stroke[7,8], development of and death from cardiovascular disease[6,9], development of diabetes[9,10], and development of breast and gastric cancer[11,12] (in some of these studies, a significant correlation was not observed). A meta-analysis that examined the association with the development of diabetes showed a significant negative correlation with cereal-derived dietary fiber intake;

however, no association with fruit- or vegetable-derived dietary fiber intake was observed[10]. This suggests that sources of dietary fiber need to be considered in terms of whether or not they are effective in preventing the development of diabetes.

A negative correlation between serum (or plasma) LDL cholesterol levels and blood pressure has also been suggested, which is a strong risk factor for cardiovascular disease[13,14]. Many epidemiological studies have also shown an association with obesity[15,16]. However, study results on the association with cancer, particularly colorectal cancer, are not always consistent[17][18]. A significant negative correlation was observed between dietary fiber intake and colorectal cancer; however, this correlation was no longer significant when the intakes of folic acid, red meat, milk, and alcohol were taken into account, which may be a reason for the inconsistent results[17]. Many epidemiological studies have examined the relationship between dietary fiber intake and LRDs. However, few studies have quantitatively (quantity response relationship) demonstrated this relationship.

Dietary fiber intake has been suggested to influence bowel habits (adverse health events such as constipation); one cross-sectional epidemiological study found a negative correlation between dietary fiber intake and the prevalence of constipation[19], whereas no Japanese studies found a correlation between the two[20].

(2) Association between Dietary Fiber and Prevention of LRD Progression

An interventional study found that 20 g/day of dietary fiber increases fecal weight, leading to better bowel movement[21], whereas another study observed an increase in fecal weight but could not conclude that this improved constipation[22]. Therefore, it remains to be fully elucidated what amount of dietary fiber consumed from a normal diet affects constipation and what percentage of dietary fiber intake contributes to better bowel habits.

The findings of a meta-analysis of interventional studies also suggested that an increased dietary fiber intake was negatively correlated with blood pressure[13]. Another meta-analysis similarly suggested a negative correlation with serum (or plasma) LDL cholesterol levels[15]. However, this effect was limited to water-soluble dietary fiber. Meanwhile, a low-glycemic index diet has also been observed to have a LDL cholesterol-lowering effect[23]. Diets with a low glycemic index are generally considered rich in dietary fiber, particularly insoluble dietary fiber. Therefore, it is deemed appropriate to recommend dietary fiber to individuals with high LDL cholesterol levels, regardless of whether it is water-soluble or insoluble.

In a meta-analysis report that summarized 15 interventional studies, which observed changes in blood glucose levels after increasing dietary fiber intake, an average decrease of 15.3 mg/dL in fasting blood glucose levels was observed with an average increase of 18.3 g/day in dietary fiber levels[24].

2-2-2-2. Methods Used to Set the DG

(1) Adults

The LRD in which the association with dietary fiber intake is the most evident is myocardial infarction. A pooled analysis that reanalyzed the accumulated data of 10 cohort studies demonstrated a decrease in myocardial infarction-related mortality with a dietary fiber intake of 24 g/day, and an increase in mortality with an intake of less than 12 g/day[5]. However, some of these studies included groups of vegetarians, and all of them were conducted in Western countries. Therefore, the dietary fiber intakes were likely larger overall than those of Japanese people. Thus, using these results poses a problem. However, a recently collected meta-analysis showed no clear threshold, and found an almost negative linear correlation with the risk (incidence or mortality) of myocardial infarction[6].

Incidentally, the AI for dietary fiber was set at 14 g/1,000 kg following a review focusing on each study used in this meta-analysis in the US-Canada DRIs (note: a DG does not exist in the US-Canada DRIs, and, therefore, AI is used instead)[4]. This value is based on the typical intake of the group in which dietary fiber was found to have the greatest preventive effect in each of these studies, and is substantially higher than 24 g/day.

Other meta-analyses that examined the development of stroke[7] and breast cancer[25] found a significant negative correlation, but no clear threshold. For this reason, it is difficult to use these findings as a basis for calculating the DG. Considering the relationship observed between dietary fiber intake and the development of and risk factors for LRDs, the significance of the DG calculated here is nebulous and should be interpreted to mean “it is best to consume as large an amount as possible without excess.” Furthermore, considering the fact that a large dietary fiber intake has not been reported to increase the risk of any LRDs, it is safe to interpret the DG as such.

Despite the above-described limitations, the ideal DG should be at least 24 g/day, and at least 14 g/1,000 kcal if possible, considering the above value. However, the median dietary fiber intake of Japanese people, based on the results of the 2010 and 2011 National Health and Nutrition Surveys[26], is much lower than this in all age groups (Table 1). Thus, the feasibility of setting this value as the DG is low. Therefore, the DG was set using the following method.

The intermediate value (18.9 g/day) between 24 g/day and the median dietary fiber intake (13.7 g/day) of Japanese adults (aged 18 years and older), currently, was set as the reference value for calculating the DG. The mean reference weight (57.8 kg) of adults (aged 18 years and older), and the reference weights of each sex and age group as well as the 0.75th power of body weight were then used to extrapolate intake with the body surface area estimation method, and calculate the DG of each sex and age group. However, the simple average of each sex and age group (all eight groups) was used for the average reference body weight.

This was calculated specifically as follows:

$$\textbf{18.9 (g/day)} \times \left[\frac{\textbf{reference body weight (kg) of each sex and age group}}{\textbf{57.8 (kg)}}\right]^{0.75}$$

After taking the integer of the value obtained with this formula, the value was equalized

between adjacent age groups (Table 1).

No additional amount was set for pregnant or lactating women.

Incidentally, most studies used in the calculation of DGs focused on the dietary fiber derived from normal food, and not dietary fiber derived from supplements, etc. The same health benefits as those described here are, therefore, not guaranteed when the equal amount of dietary fiber is consumed in the form of supplements or sources other than regular food. Furthermore, it should be noted that there is no evidence stating that greater health benefits than those described here can be expected from consuming large amounts of dietary fiber in the form of supplements or other sources in amounts that exceed those that can be consumed from regular food.

Table 1. Method used to determine the DG for dietary fiber

Gender	Male				Female			
Age (years)	(A)	(B)	(C)	(D)	(A)	(B)	(C)	(D)
1-2	-	-	-	-	-	-	-	-
3-5	-	-	-	-	-	-	-	-
6-7	10.8	9.2	11	A	10.3	9.1	10	A
8-9	11.8	11.0	12	A	11.7	10.8	12	A
10-11	12.7	13.1	13	B	12.4	13.3	13	B
12-14	14.9	16.7	17	B	13.2	16.3	16	B
15-17	14.0	19.4	19	B	11.8	17.4	17	B
18-29	11.8	20.2	20	B	10.8	17.0	18	B, ↑
30-49	12.6	21.5	20	B, ↓	11.6	17.7	18	B
50-69	14.9	20.7	20	B, ↓	15.1	17.7	18	B
70+	15.5	19.4	19	B	14.8	16.8	17	B, ↑

(A) Median value of the dietary fiber intake in NHNS2010 and NHNS2011 (g/day)
(B) Extrapolated value from the reference value for DG calculation
(C) Value of the DG determined.
(D) Value used as DG (A or B), ↑ and ↓ present the way to smooth the calculated value (up and down)

(2) Children

Constipation is an adverse health event that is frequently observed in children. Some systematic reviews summarizing the effect of dietary fiber intake on improving constipation describe the existence of reports in which dietary fiber intake improved constipation[(27)]. However, since there are no quantitative discussions, these reports cannot be used to calculate the DG. An interventional study in constipated children (aged 3–14 years) demonstrated a significant improvement in a group of 3–7-year-olds that achieved a dietary fiber intake of at least 10 g/day, and a group of 8–14-year-olds that achieved an intake of at least 14.5 g/day[(28)].

However, a number of issues remain, such as a control group not having been established (controlled before and after trial), and problems associated with the consideration of the reverse causality among other factors. Moreover, very few supplementary trials used similar study methods.

As explained before, very few reports claim that dietary fiber intake at the time of consumption is directly associated with the prevention of the development and progression of the LRDs featured in the current DRIs. It is, therefore, considered difficult to calculate the DG on the basis of these reports.

However, habitual nutrient intake over a long period of time has an effect on the development of LRDs, and other factors, suggesting that dietary habits during childhood may influence the development of and risk factors for cardiovascular disease after entering adulthood[29]. Many reports state that childhood eating habits have a certain impact on eating habits thereafter[30,31]. It is, therefore, recommended to also set DRIs for children[32]. However, it is difficult to assess intakes in children aged 1–5 years, and the details of the actual intake status in Japan are unknown. Thus, there is little evidence for the calculation of the DG for children. The DG was calculated for those aged 6–17 years using the same method as that in adults. Furthermore, the current median intake was set as the DG when the current median intake was greater than the calculated DG.

DRIs for Carbohydrates (% energy)

Gender	Males	Females
Age etc.	DG [1,2] (median [3])	DG [1,2] (median [3])
0-5 months	—	—
6-11 months	—	—
1-2 years	50-65（57.5）	50-65（57.5）
3-5 years	50-65（57.5）	50-65（57.5）
6-7 years	50-65（57.5）	50-65（57.5）
8-9 years	50-65（57.5）	50-65（57.5）
10-11 years	50-65（57.5）	50-65（57.5）
12-14 years	50-65（57.5）	50-65（57.5）
15-17 years	50-65（57.5）	50-65（57.5）
18-29 years	50-65（57.5）	50-65（57.5）
30-49 years	50-65（57.5）	50-65（57.5）
50-69 years	50-65（57.5）	50-65（57.5）
70+ years	50-65（57.5）	50-65（57.5）
Pregnant women		—
Lactating women		—

1 Ranges are expressed as approximate values.

2 Includes alcohol. However, it does not imply recommendation of alcohol consumption.

3 Medians indicate the median values for the given range. They do not indicate most desirable values.

DRIs for Dietary Fiber (g/day)

Gender	Males	Females
Age etc.	DG	DG
0-5 months	—	—
6-11 months	—	—
1-2 years	—	—
3-5 years	—	—
6-7 years	≥ 11	≥ 10
8-9 years	≥ 12	≥ 12
10-11 years	≥ 13	≥ 13
12-14 years	≥ 17	≥ 16
15-17 years	≥ 19	≥ 17
18-29 years	≥ 20	≥ 18
30-49 years	≥ 20	≥ 18
50-69 years	≥ 20	≥ 18
70+ years	≥ 19	≥ 17
Pregnant women		—
Lactating women		—

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