Guideline for dietary fibre intake

Gezondheidsraad
Health Council of the Netherlands

To the Minister of Health, Welfare and Sport

Subject : Presentation of advisory report *Guideline for dietary fibre intake*
Your reference:-
Our reference : U 383/CS/cn/754-C
Enclosures : 1
Date : March 21, 2006

Dear Minister,

I hereby present an advisory report concerning the Guideline for Dietary Fibre Intake, which has been prepared, at the request of my predecessor Professor JGAJ Hautvast, by the Health Council's Committee on Dietary Fibre and reviewed by the Standing Committee on Nutrition and the Standing Committee on Medicine. I have today also presented this report to the Minister of Agriculture, Nature and Food Quality.

This is the fourth in a series of advisory reports designed to revise the Dutch dietary reference intakes (Nederlandse Voedingsnormen), which were adopted in 1992 by the former Food and Nutrition Council (Voedingsraad). Dietary fibre received very little attention in that report, however. The advisory report Guidelines for a Healthy Diet (Richtlijnen Goede Voeding), which was published by the Food and Nutrition Council in 1986 and is currently being revised, also included a very brief passage about dietary fibre. The attached advisory report is therefore the first thorough evaluation of the physiological effects of dietary fibre to have been undertaken in the Netherlands.

The Committee has chosen not to set a dietary reference intake for fibre, but instead to issue a guideline. This decision is motivated by the fact that dietary fibre is the collective term for a group of substances with very wide-ranging physiological effects. Thus, whereas some types of dietary fibre serve mainly to promote evacuation, others help to prevent coronary heart disease. A high intake of whole-grain products appears to help prevent type-2 diabetes mellitus. Furthermore, a high-fibre diet can assist in the prevention of overweight and there may possibly be an association between a very low intake of fibre and an increased risk of colon cancer.

The guideline for all people aged 14 years and over has been set at 3.4 grams of dietary fibre per megajoule, or 14 grams of dietary fibre per 1,000 kilocalories, which amounts to 30 to 40 grams per day. For children below 14 years of age, the recommended intake progressively increases with age. How much dietary fibre a person requires per day depends

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upon his or her energy intake. The advisory report gives an indication of this requirement based on the average energy intake per age group. According to the National Food Consumption Surveys, only a small proportion of the Dutch population fulfils the guideline (in most age groups, five to ten percent).

The guideline applies to dietary fibre intake via a mixed diet consisting of products that have not been enriched with isolated and purified dietary fibre.

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to:

the Minister of Health, Welfare and Sport

the Minister of Agriculture, Nature and Food Quality

No. 2006/03E, The Hague, March 21, 2006

The Health Council of the Netherlands, established in 1902, is an independent scientific advisory body. Its remit is "to advise the government and Parliament on the current level of knowledge with respect to public health issues..." (Section 22, Health Act).

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This report can be downloaded from www.healthcouncil.nl.
Preferred citation:
Health Council of the Netherlands. Guideline for dietary fibre intake. The Hague: Health Council of the Netherlands, 2006; publication no. 2006/03E.

ISBN-10: 90-5549-604-9
ISBN-13: 978-90-5549-604-4

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Executive summary

Scope

This advisory report poses two central questions: What should be the new Netherlands guideline for dietary fibre intake? And on what reasoning is this guideline based?

Dietary fibre is the collective term for a group of substances that are not digested or absorbed in the human small intestine and which have the chemical character of carbohydrates, compounds analogous to carbohydrates, lignin, or substances related to lignin. Various substances comply with this definition. The effects of specific types of dietary fibre on the human body may be similar, but may also differ completely from one another.

In general, specific types of dietary fibre have one or more of the following physiological effects: they accelerate the transit of food through the gastrointestinal tract; they increase the amount of stool; they favourably affect fermentation in the colon; they reduce blood LDL cholesterol levels; they help improve blood glucose and blood insulin levels.

The committee formulating the new guideline was asked whether it could endorse the new American adequate intake of 3.4 grams of dietary fibre per megajoule (14 grams per 1000 kilocalories), and if not, how and why it should be changed.

The American dietary reference intakes are drawn up by the Institute of Medicine, which considers the adequate intake value to be suitable for both sexes and for all age groups, except for babies in their first year of life.

Approach

Because of the diversity of both the compounds covered by the term dietary fibre and the physiological effects of these compounds, the committee decided not to establish an adequate intake for the Netherlands but to formulate a guideline instead.

The committee then investigated whether the American value of 3.4 grams per megajoule was a suitable guideline for the Netherlands population. This involved examining the substantiation given in the American report, evaluating whether the reasoning followed could also be applied to the Netherlands situation, and assessing whether any research results since the publication of the American report suggest that the guideline value should be revised.

Central to this analysis was the potential effect of dietary fibre on constipation, coronary heart disease, type-2 diabetes mellitus (maturity-onset diabetes), obesity and colon cancer, as these are the effects for which most research findings are available and for which the evidence of a dietary fibre involvement is strongest. The committee's analysis resulted in the following conclusions:

- Dietary fibre increases the speed at which food passes through the gastrointestinal tract and can thus reduce the risk of constipation. The required level of fibre intake for optimal intestinal transit speed in adults is, in the case of a mixed diet, 32 to 45 grams per day. Furthermore, it is essential that people also have a sufficiently high fluid intake and take enough physical exercise.
- A high-fibre diet protects against coronary heart disease. The lowest risks are found at the highest levels of fibre intake (between 3.1 and 3.5 grams of dietary fibre per megajoule). There is evidence that fibres from whole-grain products and fruit are particularly effective at protecting against coronary heart disease.
- There is quite strong evidence that a high intake of whole-grain products can protect against type-2 diabetes mellitus. However, the protective effect of the total fibre intake has not been convincingly demonstrated.
- A high-fibre diet is important for preventing weight gain. It is not possible, however, to specify an optimal consumption level that would optimise this effect.
- In observational research, people with a very low fibre intake exhibited an increased risk of colon cancer. The differences between studies are, nonethe-

less, too great to allow conclusions to be drawn regarding other levels of consumption.

Guideline for adults

In the light of the above conclusions, the committee has based its guideline for adults on the importance of fibre for the intestinal function and its protective effect against coronary heart disease.

Although there is still some uncertainty regarding the optimum consumption level, the committee considers the American value of 3.4 grams of dietary fibre per megajoule (14 grams per 1000 kilocalories) to be a suitable guideline for adults in the Netherlands.

The value of the guideline is based on the most important studies on the association of fibre intake with the risk of coronary heart disease. This guideline recommends a daily level of fibre consumption in grams that is considered desirable for the smooth transit of food through the gastrointestinal tract.

The association established between high fruit-fibre consumption and a low risk of coronary heart disease is supported by the fact that pectin – one of the most important types of fibre found in fruit – reduces blood LDL cholesterol levels (LDL cholesterol levels are an important risk factor in coronary heart disease). Although an association has also been established between high cereal fibre consumption and a low risk of coronary heart disease, there is no evidence that the specific isolated and purified types of dietary fibre found in many cereals reduce blood LDL cholesterol levels. The protective effect could, of course, be due to other mechanisms of action, but the scientific research available is unable to confirm whether the ability of whole-grain products to protect against coronary heart disease is indeed due to the fibre fraction of these products. It is conceivable that the protective effect is due to other components of, for example, the cereal bran. This uncertainty reinforces the committee's decision to deduce a guideline rather than specify an adequate intake. The guideline applies to the fibre intake achieved via a mixed diet consisting of products that have not been enriched with isolated and purified dietary fibre.

Guideline for children

The committee has opted for a children's dietary fibre guideline that gradually increases with age: 2.8 grams per megajoule for the age group 1 to 3 years; 3.0 grams per megajoule for the age group 4 to 8 years; 3.2 grams per megajoule for

the age group 9 to 13 years, and then the adult value (3.4 grams per megajoule) for the age group 14 to 18 years.

This decision is underpinned by the findings of the National Food Consumption Survey, which revealed that Dutch children rarely or never consume 3.4 grams of dietary fibre per megajoule, while approximately 10% of adolescents and adults do. It is conceivable that recommending an adult guideline value could jeopardise the energy intake of the youngest children. It is unknown whether fibre consumption at such an early age helps to prevent coronary heart disease in later life. Moreover, the adult guideline is based on studies on the effect of dietary fibre on the intestinal transit speed in adults.

No upper intake limit

The committee supports the decision of the American Institute of Medicine not to specify an upper limit for fibre intake. Consumption of products that are naturally rich in fibre is self-limiting due to their bulky nature, although this is less true of supplements and products enriched with dietary fibre.

Chapter 1

Introduction

1.1 Scope

Dietary fibre is the collective term for those parts of plant-based food products that are not digested or absorbed in the human small intestine. In many studies, a high intake of dietary fibre has been associated with beneficial health effects. People who eat plenty of fibre are supposed to have better gut function and a lower risk of developing certain diseases and disorders. This advisory report assembles the available scientific data and then proceeds to formulate a guideline for daily intake of dietary fibre.

Historical background

Dietary reference intakes have a fairly long history in the Netherlands (see Annex A for a historical overview). Previously formulated standards are regularly reviewed in the light of the current level of knowledge. Since 1997, the Health Council's Committee on Dietary Reference Intakes has formulated revised reference intakes for calcium, B vitamins, energy, proteins, digestible carbohydrates and fats.[1-3] That Committee has meanwhile been abolished. Work on the revision of the dietary reference intakes continues, however, though committees are now appointed per nutrient.

Since 1986, the recommended dietary fibre intake in the Netherlands has been 3 grams per megajoule per day.[4,5] See Annex B for a brief outline of the former Dutch recommendation concerning dietary fibre intake and the dietary fibre recommendations in the Nordic and German-speaking countries. In view of the large increase in knowledge about dietary fibre in the past two decades, the Vice-President of the Health Council has decided to revise this recommendation (after consulting the Standing Committee on Nutrition).

Revision: remit and approach

The Vice-President of the Health Council set up the Committee on Dietary Fibre on 23 September 2003 with the remit of establishing a new dietary reference intake. The membership of the Committee can be found in Annex C. The Vice-President has asked the Committee to investigate whether it is possible to base the new Dutch reference intake for dietary fibre on an authoritative American recommendation, namely that of the US Institute of Medicine.[6]

Why choose this as the starting point? The American report pooled the efforts of a large number of experts backed by an extensive team of scientists. Both their approach and the outcome are thorough and comprehensive, and their assessment reflects the current level of scientific knowledge. It would therefore seem likely at first glance that the American recommendations are also applicable to the Dutch population, unless research that has been published since the appearance of the American report should indicate otherwise.

The Institute of Medicine has decided on an adequate intake of 3.4 grams of dietary fibre per megajoule for both sexes and for all age groups. The question to be answered by the Committee is whether it can endorse the US Institute of Medicine's dietary reference intakes for dietary fibre, and if not, in what respects and based on which scientific data or reasoning it would wish to modify these values.

This advisory report explores the extent to which the current state of knowledge reveals an association between fibre intake and the risk of developing certain diseases or disorders. Five are examined, including constipation, coronary heart disease, type-2 diabetes mellitus, overweight and colon cancer. These are the conditions for which there is most evidence that dietary fibre may play a role in their development.

For each disease or disorder, the Committee makes an assessment about the possible role of dietary fibre and investigates whether it is known what amount

of dietary fibre is associated with a particular effect. The report also considers what is known about the effects of specific types of fibre.

The conclusions drawn for each condition form the basis for the derivation of the guideline.

1.2 Why merely a guideline?

Dietary fibre is the collective term for a group of substances that is extremely diverse in character and function. In general, substances that are designated as fibre have one or more of the following physiological effects: they accelerate food transit through the gastrointestinal tract, increase faecal bulk, influence fermentation in the colon, lower blood LDL cholesterol levels and/or have a beneficial effect on blood glucose and insulin levels. Cellulose, for example, has a beneficial effect on stool weight but not on blood lipids, whereas (almost) the reverse applies in the case of pectin.

Dietary reference intakes are set for essential, well-defined and simple nutrients, but it is manifestly impossible to formulate a dietary reference intake for the complex group of compounds referred to with the term dietary fibre. By way of comparison, it would also be impossible to establish a general dietary reference intake for total vitamin content. However, although one can derive reference intakes for individual vitamins, the current state of knowledge renders that impossible for specific types of dietary fibre.

The Committee has therefore decided to establish a guideline with regard to recommended dietary fibre intake, rather than setting an ‘adequate intake’. In doing so, the Committee is indicating that the specified value is less rigid than a dietary reference intake.

Since the guideline is being formulated for the healthy population, the effect of dietary fibre intake in patients with intestinal problems (such as irritable bowel syndrome) is not explored.

1.3 Definition of dietary fibre

Dietary fibres are resistant to human digestive enzymes and are not absorbed into the small intestine. Most of the dietary fibre that we consume (an estimated 70 to 80 per cent in the case of a mixed diet [7]) is broken down by bacteria in the colon. Providing they are absorbed from the gut into the body, fermentation products can also exert effects elsewhere in the body.

McCance and Lawrence first made the distinction between ‘available’ and ‘non-available’ carbohydrates in 1929.[8] The term ‘dietary fibre’ was coined in 1953 to refer to components of plant cell walls that humans are unable to digest.

It was subsequently discovered that the cell wall is not the only indigestible component of a cell. The definition was then extended to embrace all indigestible polysaccharides and lignins present in plant-based foods.[9]

However, the fact that a number of the indigestible substances included in this definition do not have a fibrous structure (examples being pectin, gums and mucilages) militates against the use of the term dietary fibre.[10] Some authors therefore use the term ‘indigestible residue’.[11,12] Annex D contains a list of older, and more recent, definitions of dietary fibre.

The Committee uses the term ‘dietary fibre’ in this advisory report on account of its recognisability and international use. It defines dietary fibre as ‘carbohydrates, compounds analogous to carbohydrates, and lignin and related substances that are not digested or absorbed in the human small intestine’. The substances that conform to the definition of dietary fibre are extremely diverse in character. By way of illustration, a number of substances that satisfy the definition are listed in Table 1. Annex E gives the sources of various types of dietary fibre mentioned in this advisory report.

Table 1 Examples of substances that fall under the definition of dietary fibre (this list is not exhaustive).

Group	Type of dietary fibre
Polysaccharides other than starch, and indigestible oligosaccharides	cellulose hemicelluloses such as arabinoxylans, arabinogalactans and xyloglucans pectin fructans and some oligosaccharides (inulin, fructo-oligosaccharides, oligofructose) galacto-oligosaccharides and xylo-oligosaccharides gums and mucilages for some population groups: lactose
Compounds analogous to carbohydrates	indigestible dextrins (mainly from potatoes and maize) synthetic carbohydrates and their derivatives polydextrose, methylcellulose, hydroxypropyl methylcellulose, etc. indigestible starch
Lignin	lignin
Substances that occur in products containing lignin or polysaccharides other than starch	wax cutin saponins suberins tannins

1.4 Interpretation of research data

There are four reasons why results from different studies concerning the effects of dietary fibre intake are not always entirely comparable. We explain below the extent to which these factors can influence the research outcomes.

1 Different methods of determining the fibre content of foods result in different values

There are different methods for determining the fibre content of foods. Two methods are of relevance to the assessment that is being undertaken in this advisory report: that of the Association of Official Analytical Chemists (AOAC), which is favoured in the United States (and elsewhere), and the method developed by Englyst, which is used in the UK and Finland.

In the AOAC method, resistant starch (starch that is not broken down by the digestive enzymes) and lignin are counted as dietary fibre, whereas this is not the case with the Englyst method.[13] The Englyst method therefore results in a lower fibre content than the AOAC method. In a comparative study, the estimate of total fibre content was 21 per cent higher using the AOAC method than with the Englyst method.[14]

In the Netherlands, food consumption data are converted into nutrients with the aid of the Netherlands Nutrient Databank (NEVO). Quantitative data from American research on the association between dietary fibre intake and disease are more useful than British or Finnish data. This is because the AOAC method, which is regarded as the standard procedure in North America, is also the preferred method in the Netherlands. Data from British and Finnish research into dietary fibre intake are likely, owing to the different method used, to produce an underestimate of the Dutch situation.

As far as the interpretation of the research outcomes is concerned, this means that although the method of analysis does not influence the strength of the association between fibre intake and disease risk [15], it does indeed affect the estimate of optimal fibre intake.

2 Different methods of investigating food consumption result in different estimates of dietary fibre intake

Food consumption surveys are necessary in order to discover exactly what people eat, and therefore what dietary fibre they consume. Different methods are also used when conducting these surveys.

In the 24-hour recall method, participants are interviewed about their food intake during the previous day. Food record methods, which are usually conducted over several days, require the subject to note down in a diary what he or she eats and drinks during the period under investigation. The dietary history method and food frequency questionnaires are used to determine average consumption of foods over a longer period. The intake data collected using the latter two methods always show a wider statistical distribution than intake data that are obtained using such precise techniques as the repeated 24-hour recall or food record methods.

The European Prospective Investigation into Cancer and Nutrition (EPIC) gives an impression of the impact of the food consumption survey method on dietary fibre intake estimates and on estimates of the association of dietary fibre intake with disease. The data that have been obtained in this study using a food frequency questionnaire were, in fact, calibrated against a repeated 24-hour recall. This was done in order to adjust for differences in food frequency questionnaires between countries.

The investigators assume that the repeated 24-hour recall approximates actual dietary fibre intake more closely than the food frequency questionnaire, although the former method can likewise not be regarded as a gold standard. There was some attenuation of the association between dietary fibre intake and disease with the uncalibrated data, which means that an association that actually exists between dietary fibre intake and disease is less evident from the uncalibrated research data.[16] In the Dutch EPIC cohort, the average dietary fibre intake that was determined in the highest quintile of fibre intake using a repeated 24-hour recall was 7-8% lower than the value determined with a food frequency questionnaire (unpublished data, source: EJM Feskens). This applied both to intake in grams per megajoule and intake in grams per day.

If the guideline for fibre intake is based on the 90th percentile of fibre consumption (as in the case of the American adequate intakes), then one would expect (on the basis of this analysis of the EPIC data) there to be an overestimate.

3 There are major between-country differences in the composition of total dietary fibre intake

Dietary fibre is the collective term for a group of substances that is extremely diverse in character and activity. For specific effects, this means that what counts is not the total dietary fibre intake, but the consumption of those types of fibre that have the effect in question. The proportion of total dietary fibre intake provided by substances with a specific function will vary from one population to another. In populations where the relevant substances provide only a small proportion of total intake, there will be less likelihood of an association being found between total dietary fibre intake and the disease in question.

A potentially important difference between countries in this connection is the relative contribution that cereal fibre consumption makes to total dietary fibre intake. In US studies, cereal fibres provide 25 to 30 percent of total dietary fibre intake[17-19], whereas cereals provide 55 to 70 percent of total dietary fibre intake in Scandinavian countries.[20,21] The contribution made by fibre from both vegetables and fruit to the total dietary fibre intake in these US studies is twice as high as in the European studies.

As far as research into effects that are principally caused by cereal fibre is concerned, there is less likelihood of associations being found between total dietary fibre intake and the effect in question among populations in which cereal fibre accounts for a smaller proportion of total dietary fibre intake. The same can, of course, be said mutatis mutandis of fruit fibre and also, in theory, of specific types of fibre. Little is known, however, about the contribution of specific types of fibre to total dietary fibre intake in the different countries.

4 Regulatory differences between countries

Owing to legislative and regulatory differences, the composition of some Dutch foods probably differs more from that of the equivalent US product than from equivalent products in Northern European countries. These differences do not, however, pose a problem for research into the effects of nutrient consumption (total fibre, cereal fibre, fruit fibre, fibre from vegetables), and it is precisely this type of research that is under the spotlight in this advisory report. Differences in legislation and regulations governing product composition could well influence the outcomes of research at the product level (food products).

1.5 Structure of the advisory report

In chapters 2 - 6, the Committee successively discusses the evidence for a possible beneficial effect of a high dietary fibre intake on constipation, cardiovascular disease, type-2 diabetes, overweight and cancer of the colon.

Each discussion has been broken down into what is known about the effect of the total dietary fibre intake and the effects of specific types of dietary fibre. The findings of the Institute of Medicine are always reported first[6], with the Committee then presenting its own findings. In general, these will consist of research that has emerged since the publication of the American report. However, the chapter on constipation also considers earlier studies, since in this case the Committee adopts a somewhat different approach from the Institute of Medicine. At the end of each chapter, the Committee draws a conclusion about the association between the discussed disease or disorder and the intake of dietary fibre.

An optimal level of intake is then derived in the final chapter. We first explain what effects of dietary fibre may influence this decision and what uncertainties are involved in this.

Chapter 2

Constipation

Dietary fibre exerts effects in the gastrointestinal tract. When dietary fibre intake increases, faecal weight increases and transit time through the gut decreases. Low fibre intake is associated with an increased risk of constipation.

2.1 Effects of total dietary fibre intake

2.1.1 Opinion of the Institute of Medicine

The Institute of Medicine concluded that some types of dietary fibre have beneficial effects on constipation, laxation and faecal weight, and possibly also help to prevent duodenal ulcers and diverticular disease.[6] Dietary fibre also provides an energy source for the body's cells via bacterial breakdown products. According to the Institute of Medicine, however, none of these effects provides sufficient information to determine the optimal level of dietary fibre intake with regard to the prevention of constipation.

2.1.2 The Committee's findings

Various estimates have been made in the scientific literature of the level of dietary fibre intake that is required in order to maintain proper gut function. As far as the prevention of constipation is concerned, proper gut function depends on

two interrelated variables: transit time through the gastrointestinal tract and daily faecal weight. On this basis, it is possible to arrive at an estimate of desirable dietary fibre intake via the following three steps.

1 What faecal weight is required for a satisfactory intestinal transit time?

A publication by Spiller considered the faecal weight that is required in order to help ensure a good intestinal transit time.[22] If faecal weight falls below a threshold of 160 to 200 grams per day, there is a strong association between the weight of the faeces and the time it takes for food to pass through the gut: the less faeces there is, the longer the transit time. Above this threshold, the association disappears and intestinal transit almost always takes place within two days.

2 How strong is the association between intestinal transit time and constipation?

Constipation is diagnosed if someone who is not suffering from irritable bowel syndrome has satisfied two of the following six criteria for at least 12 weeks (not necessarily consecutive) in the past year:[23]

- Straining during at least one in four bowel movements
- Large or hard stools during at least one in four bowel movements
- Feeling of incomplete evacuation during at least one in four bowel movements
- Feeling of obstruction/blockage in the anus or rectum during at least one in four bowel movements
- Manual assistance required during at least one in four bowel movements
- Less than three bowel movements per week.

The final criterion relates to the frequency of bowel movements and thus, to some extent, the transit time through the gut. The other five criteria have no direct bearing on the faecal weight and intestinal transit time. This definition shows that constipation may be, but does not have to be, associated with slow intestinal transit. Treatment of constipation usually begins with an increase in the consumption of dietary fibre.

3 At what level of dietary fibre intake is optimal faecal weight achieved?

Four groups of nine young women were compared in an intervention study. The women ate bread containing different levels of wheat bran as part of their normal diet.[24] Based on this study, Spiller estimated that the 'critical' faecal weight of 160 to 200 grams is achieved with a dietary fibre intake of 35 to 45 grams per day.[22]

Cummings *et al*. arrived at the following regression comparison in a meta-analysis of 11 studies involving people with a mixed diet: faecal weight = 4.9 x dietary fibre intake + 35.[25] The Englyst method was used for the fibre analyses. Based on this regression comparison, an average faecal weight of 160 to 200 grams would be attained upon consumption of 26 to 34 grams of dietary fibre.

Monro also estimated how much dietary fibre needs to be consumed in order to attain a faecal weight of 160 to 200 grams.[26] He determined the faecal bulking index of 66 foods (including different sorts of bread, biscuits, vegetables, fruit, legumes, breakfast cereals and muesli bars) in rats, using wheat bran as a reference. This author maintains that rats can be used as a model for humans, citing the results of a validation study. The fibre contents of the investigated products were determined using the AOAC method. The fibre content of foods displayed a linear correlation with the faecal bulking index. When the products with the highest fibre content were included in the regression analysis, the fibre content accounted for 83 per cent of the variation in faecal weight (R^2=0.83), whereas it accounted for 46 per cent when these products were excluded. Based on his regression comparisons, Monro estimated that a faecal weight of 160 to 200 grams per day is attained when 32 to 40 grams of dietary fibre is consumed.

2.2 Effects of different dietary fibre types*

The Institute of Medicine indicates which isolated types of dietary fibre have been found to have a laxative effect in intervention research:[6]

- Several types of dietary fibre increase faecal weight, transit time through the gastrointestinal tract, or both: cellulose, inulin, fructo-oligosaccharides, polydextrose, psyllium, resistant starch and fibre from oats. Pectin had a small effect. These types of dietary fibre have a preventive effect against constipation, providing that fluid intake is adequate.

* See Annex E.

- Other types of dietary fibre (chitin, chitosan, guar gum, beta-glucans and dextrins) have little or no effect on faecal weight and/or intestinal transit time.

One of the publications cited by the Institute of Medicine is a meta-analysis from 1993, in which Cummings concluded, on the basis of nearly one hundred studies in humans, that the effect of dietary fibre on faecal weight depends on the type of consumed fibre.[7] He estimated that the increase in faecal weight per gram of fibre ranges from 1.2 grams (pectin) to 5.4 grams (wheat fibre). The estimated increase in faecal weight for 1 gram of fibre from vegetables and fruit was 4.9 grams.

2.3 Conclusion

The Committee concludes that dietary fibre has an important bearing on the rate at which food passes through the gastrointestinal tract. As a result, the consumption of dietary fibre reduces the risk of constipation.

The amount of fibre that is needed in order to attain the 'critical' faecal weight of 160 to 200 grams per day varies from study to study. The lowest estimate comes from Cummings (26 to 34 grams per day). The estimates produced by Monro (32 to 40 grams per day) and Spiller (35 to 45 grams per day) are higher and more similar to each other. This difference can be partly explained by the manner in which dietary fibre content has been determined.

Because the AOAC method is regarded as the standard in the Netherlands, the Committee estimates the dietary fibre intake that is required for optimal gut function (in adults) to be 32 to 45 grams per day, emphasising that adequate fluid intake and physical activity are extremely important. This level of intake has been measured in more than ten percent of adult men and over five percent of adult women in the Netherlands (see Annex F).

Annex 3

Coronary heart disease

In observational research, higher dietary fibre intake has been found to correlate with a lower risk of coronary heart disease. This finding is supported by results from intervention research that show that certain types of fibre have beneficial effects on risk factors for coronary heart disease, such as the concentrations of total and LDL cholesterol in the blood.

3.1 Effects of total dietary fibre intake

3.1.1 Opinion of the Institute of Medicine

The Institute of Medicine found sufficient evidence to support the use of a reduction in the risk of coronary heart disease by dietary fibre as a criterion for establishing adequate dietary fibre intake. This conclusion is based, on the one hand, on results of prospective cohort research that showed that higher dietary fibre intake correlates with a lower risk of coronary heart disease, and, on the other hand, on results of intervention studies that show that an increase in dietary fibre intake leads to beneficial changes in risk factors for coronary heart disease.

The American adequate intake value is based on the results of three cohort studies concerning the intake of dietary fibre and the risk of coronary heart disease: a Finnish cohort of male smokers (the Alpha-Tocopherol, Beta-Carotene Cancer Prevention Study*)* [21] and two American cohorts – a cohort of men work-

ing in healthcare (the Health Professionals Follow-up Study)[18] and a cohort of nurses (the Nurses' Health Study)[19]. The risk of fatal coronary heart disease in these studies was higher (after adjustment for age) in the lowest consumption category than in the highest consumption category (see Table 2).

3.1.2 *Recent findings*

In 2004 Pereira *et al*. published a pooled analysis of the results of prospective cohort studies published between 1988 and 2002.[20] These ten studies consisted of the three studies on which the Institute of Medicine had based its conclusions and seven other prospective cohort studies.* After adjustment for various confounding variables** and for measurement error, each 10 g/day increase in dietary fibre intake was associated with a 14 per cent decrease in the risk of coronary heart disease and a 27 per cent decrease in the risk of fatal coronary heart disease (see Table 2).

Three publications from 2003 were not incorporated in Pereira *et al*.'s pooled analysis: the National Health and Nutrition Examination Survey (NHANES), the Cardiovascular Health Study and the Los Angeles Atherosclerosis Study. The last-named study determined the association between dietary fibre intake and the change in the thickness of an arterial wall, and not the correlation with the incidence of coronary heart disease.

Although a high dietary fibre intake was, indeed, associated with a lower risk of non-fatal and fatal coronary heart disease in the National Health and Nutrition Examination Survey (NHANES), these findings were not statistically significant (Table 2).[27] There are two explanations for the fact that the associations in this study are weaker than in the previous large cohort studies. First, a less accurate method was employed to determine dietary fibre intake in this study than in the other studies, namely a single 24-hour recall (i.e. interviewing participants about their food intake during the previous day). Because food intake varies greatly from day to day, asking about food intake on one particular day provides a less

* The Pereira *et al*. study incorporated the following ten studies: Adventists Health Study (AHS), Atherosclerosis Risk in Communities Study (ARIC), Alpha-Tocopherol, Beta-Carotene Cancer Prevention Study (ATBC), Finnish Mobile Clinic Health Examination Survey (FMC), Glostrup Population Study (GPS), Health Professionals Follow-up Study (HPFS), Iowa Women's Health Study (IWHS), Nurses' Health Study 1980-1986 (NHSa), Nurses' Health Study 1986-1996 (NHSb), Vasterbotten Intervention Program (VIP) and Women's Health Study (WHS).

** Adjustment for the following confounding variables: energy intake, smoking behaviour, body mass index, physical activity, educational level, alcohol consumption, use of multi-vitamin supplements, hypercholesterolaemia, hypertension, energy intake-adjusted quintiles of consumption of saturated fat, polyunsaturated fat, cholesterol, folic acid and vitamin E.

accurate estimate of average dietary fibre intake than asking participants about their habitual diet (the method that was used in the other studies featured in Table 2). Second, this is the only prospective cohort study in which an adjustment has also been made in the data analysis for the serum cholesterol concentration. Because the association between dietary fibre intake and the risk of coronary heart disease is probably attributable in part to an effect on serum cholesterol, adjustment for serum cholesterol in the analyses leads to overcorrection, as a result of which the association between dietary fibre intake and disease becomes less evident. In the Cardiovascular Health Study, the risk of cardiovascular disease after adjustment for confounding variables was 16% lower in the group with the highest dietary fibre intake than in the group with the lowest dietary fibre intake, but this difference was not statistically significant (Table 2).[17] An explanation for the absence of a significant effect is the fact that the study population was far smaller than in the other studies. The statistical power of this study is therefore low.

The Los Angeles Atherosclerosis Study is a prospective cohort study with a 3-year follow-up.[28] As a measure of atherosclerosis, the changes in the thickness of the carotid artery wall were determined over a period of three years in 500 men and women without cardiovascular diseases. After adjustment for various confounding variables*, higher dietary fibre intake was associated with a slower progression of atherosclerosis but the association was not statistically significant ($p=0.06$). In subjects with a higher dietary fibre intake, the ratio between the concentrations of total cholesterol and HDL cholesterol in the blood was lower, which indicated a lower risk of coronary heart disease. When an adjustment was made in the data analysis for blood lipids (the serum concentrations of HDL and LDL cholesterol and triglycerides), an association between higher dietary fibre intake and less atherosclerosis was no longer observed. This finding supports the hypothesis that the effect of dietary fibre intake on the risk of coronary heart disease is partly mediated by an effect on blood lipids.

* Adjustments were made in this analysis for ethnicity, smoking behaviour, physical activity, stress, diabetes, body mass index, systolic blood pressure, the use of cholesterol-lowering drugs, antihypertensives and vitamin C and E supplements, and for the consumption of vegetables, fruit, saturated fat, magnesium and potassium.

Table 2 Results of prospective cohort studies into the effect of dietary fibre on coronary heart disease.

Publication	cohort size	Years of follow-up	Number of incidences	
			All coronary heart disease	Fatal coronary heart disease
Institute of Medicine				
Alpha-Tocopherol, Beta-Carotene Cancer Prevention Study[21]	21,930	6	1,399	635
Health Professionals Follow-Up Study[18]	44,757	6	734	229
Nurses' Health Study[19]	68,782	10	591	162
Pooled analysis of ten cohort studies, including the three aforementioned studies[20]	336,244	- [c]	5,249	2,011
More recent research				
National Health and Nutrition Examination Survey; NHANES[27]	9,776	19	1,843	668
Cardiovascular Health Study[17]	3,588	8.6	467	159

a M = men; F = women

b Population divided into quintiles of total dietary fibre intake, unless otherwise stated.

c A total of 2,506,581 person-years.

d Quartiles of fibre intake in grams per megajoule.

e Relates to the risk of all cardiovascular diseases and therefore not the specific risk of coronary

M/F[a]	Median fibre intake in grams per day (g/MJ)[b]		Relative risk (95% confidence interval) for highest versus lowest quintile	
	Lowest consumption category	Highest consumption category	All coronary heart disease	Fatal coronary heart disease
M	16 (1.4)	35 (3.1)	0.87 (0.73-1.04)	0.73 (0.56-0.95)
M	12 (1.5)	29 (3.5)	0.64 (0.47-0.87)	0.45 (0.28-0.72)
F	12 (1.7)	23 (3.4)	0.77 (0.57-1.04)	0.41 (0.23-0.70)
M/F	No comparison of quintiles of fibre intake; effect determined per 10 g fibre per day		0.86 (0.78-0.96) per 10 g/d extra dietary fibre intake	0.73 (0.61-0.87) per 10 g/d extra dietary fibre intake
M/F	6 (0.8) [d]	21 (3.3) [d]	0.88 (0.74-1.04)	0.85 (0.65-1.10)
M/F	5	29	0.84 (0.66-1.07) [e]	-

heart disease (as in the other studies).

Effect on blood pressure

The total intake of dietary fibre has a modest effect on blood pressure. It is unclear whether the type of fibre also plays a role in the effect on blood pressure. The type of fibre does play a role in the effect on the cholesterol level (see section 3.2.5).

A meta-analysis was published in 2005 of 24 randomised, placebo-controlled intervention studies into the effect of fibre supplementation on blood pressure.[29] This meta-analysis covered the research published prior to 2003. The use of a fibre supplement (average dose: 11.5 grams per day) reduced systolic blood pressure by an average of 1.13 mmHg (95% confidence interval: -2.49 to 0.23) and reduced diastolic blood pressure by an average of 1.26 mmHg (95% confidence interval: -2.04 to -0.48).

The fall in blood pressure was more marked among people aged 40 years and over than among younger people, and more marked among people with elevated blood pressure than among those with normal blood pressure.

Effect on stroke

The Nurses' Health Study investigated the association between dietary fibre intake and the risk of stroke (cerebral haemorrhage or infarction).[30] The association between total dietary fibre intake and risk of stroke was not statistically significant (p=0.07).

3.2 Effects of different dietary fibre types

*3.2.1 Specific types of dietary fibre**

Intervention studies have been used to investigate the effects of specific types of dietary fibre on risk factors for coronary heart disease. The Institute of Medicine provided a comprehensive review of the available studies.[6] The results of these studies supported the findings from observational research. The IOM review is summarised below.

Beneficial effects on blood lipids (the levels of cholesterol, cholesterol fractions and triglycerides in the blood) have been discovered for pectin, guar gum and psyllium. The reported reductions in the concentrations of total and LDL cholesterol range between 5 and 15 per cent. Furthermore, pectin may possibly increase

* See Annex E.

the excretion of bile acids and cholesterol in the faeces. An association was observed in the Los Angeles Atherosclerosis Study between higher pectin consumption and slower progression of carotid artery wall thickness.[28] Guar gum was reported to have a lowering effect on the triglyceride concentration in one study and an antihypertensive effect in another.

Cellulose, fructo-oligosaccharides and resistant starch probably have no effect on the blood-lipid profile.

The effects of beta-glucans, chitin, inulin and polydextrose on the blood lipids are as yet unclear. Although oat products and oat bran appear to lower the concentration of LDL cholesterol in the blood, the effect of beta-glucans is less clear, according to the Institute of Medicine. Studies into the effects of chitin and inulin on blood lipids do not provide a consistent picture. A lowering effect on the concentration of HDL cholesterol in the blood was discovered in one study with polydextrose, whereas there was no effect on other blood lipids.

3.2.2 *Categories of fibre: fibre from cereals, fruit and vegetables*

Pereira *et al*.'s pooled analysis of the results of observational research (see also section 3.1.2) described the association between the consumption of fibre from cereals, fruit and vegetables and the risk of coronary heart disease.[20] The results are presented in Table 3 and the findings are explained in the pages that follow.

Not all of the studies included in the Pereira *et al*. analysis have been included in the formulation of the Institute of Medicine's opinion.

Table 3 Pooled analysis of the results of ten prospective cohort studies: relative risks for coronary heart disease for each 10 g/day increase in dietary fibre intake from cereals, fruit or vegetables.[20]

Type of fibre	All coronary heart disease	Fatal coronary heart disease
Cereal fibre	0,90 (0,77-1,07)	0,75 (0,63-0,91)
Fibre from fruit	0,84 (0,70-0,99)	0,70 (0,55-0,89)
Fibre from vegetables	1,00 (0,88-1,13)	1,00 (0,82-1,23)

Cereal fibre

In the pooled analysis of ten prospective cohort studies, each increase of ten grams per day in the consumption of dietary fibre from cereals was associated with a 25 per cent decrease in the risk of fatal coronary heart disease. No statistically significant effect was discovered for all coronary heart disease (see Table 3).[20] In the Cardiovascular Health Study, the risk of all cardiovascular diseases was 21 per cent* lower in the quintile with the highest consumption of cereal fibres than in the lowest quintile.[17]

In an extensive intervention study conducted among people who had recovered from myocardial infarction, the group that had received advice to increase their cereal fibre intake had a slightly higher mortality than other subjects, but the difference was not statistically significant.[31]

The effect of oat bran supplementation on blood cholesterol levels was determined in a meta-analysis of twenty intervention studies.[32] The average effect on the blood total cholesterol level was -0.13 mmol/L (95% confidence interval: -0.19 to -0.02).

It was recently reported that higher consumption of cereal fibre correlates with a lower risk of stroke. In the Nurses' Health Study, the risk was 34 per cent** lower in the highest quintile than in the lowest.[30] The risk was 22 per cent*** lower in the Cardiovascular Health Study.[17]

Fibre from vegetables

In the pooled analysis of ten prospective cohort studies, no association was found between consumption of dietary fibre from vegetables and the risk of coronary heart disease (see Table 3).[20]

Furthermore, no association**** was found in the Cardiovascular Health Study between the consumption of fibre from vegetables and the risk of all cardiovascular diseases.[17]

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* Relative risk = 0.79; 95% confidence interval: 0.62 to 0.99.
** Relative risk = 0.66; 95% confidence interval: 0.52 to 0.83.
*** Relative risk = 0.78; 95% confidence interval: 0.64 to 0.95.
**** Relative risk = 1.08; 95% confidence interval: 0.86 to 1.36.

Fibre from fruit

In the pooled analysis of ten prospective cohort studies, each 10 g/day increase in the consumption of dietary fibre from fruit was associated with a 16 per cent decrease in the risk of coronary heart disease and a 30 per cent decrease in the risk of fatal coronary heart disease (see Table 3).[20]

In the Cardiovascular Health Study, high consumption of fruit fibre was not associated with the occurrence of all cardiovascular diseases, but was associated with an increased risk of fatal coronary heart disease*.[17] The investigators were unable to explain this anomalous finding, which they attribute to chance or inadequate adjustment for confounding variables.

Water-soluble fibre

In some observational studies, the analysis by dietary fibre type has been based not on dietary fibre intake from each product group (cereals, vegetables and fruit), but on a breakdown into water-soluble (viscous) and non-water-soluble (non-viscous) dietary fibre. Examples of water-soluble dietary fibre types are pectin, gums and mucilages.

In the National Health and Nutrition Examination Survey (NHANES), higher consumption of water-soluble dietary fibre was associated with a lower risk of all (fatal and non-fatal) coronary heart disease, a lower risk of fatal coronary heart disease, and a lower risk of cardiovascular disease in general.[27] In this survey, the associations with water-soluble fibre were stronger than those with total dietary fibre intake.

In the Los Angeles Atherosclerosis Study, higher consumption of water-soluble dietary fibre was associated with slower progression of carotid artery wall thickness.[28]

3.3 Conclusion

Based on the available prospective cohort research and the results of intervention studies into effects of fibre supplementation on risk factors for coronary heart disease, the Committee concludes that a high-fibre diet provides protection against coronary heart disease. The lowest risk was identified in the highest con-

* Cardiovascular Health Study: The relative risk for the highest versus lowest quintile of fruit-fibre consumption was 0.99 for all cardiovascular diseases (95% confidence interval: 0.78 to 1.25) and 1.32 for fatal coronary heart disease (95% confidence interval: 1.02 to 1.72).

sumption category, with a median* dietary fibre intake of 3.1 to 3.5 grams of dietary fibre per megajoule. There is some evidence to suggest that fibres from cereals and fruit are particularly protective against coronary heart disease.

* The median dietary fibre intake in a study population is the middle value after the intake values have been placed in increasing order.

Chapter 4

Type-2 diabetes mellitus

There is evidence to suggest that dietary fibre intake, and particularly the consumption of whole-grain products, can influence the development of type-2 diabetes mellitus.

4.1 Effects of total dietary fibre intake

4.1.1 Opinion of the Institute of Medicine

Some of the cohort studies that were available to the Institute of Medicine did, and some did not, reveal an association between the intake of fibre and the risk of type-2 diabetes mellitus.[6] The Institute of Medicine concluded that the consumption of dietary fibre may possibly protect against type-2 diabetes mellitus, but that this has not been convincingly demonstrated. It was noted that the research data supporting this association would not lead to a higher guideline value than that derived by the Institute of Medicine on the basis of research into coronary heart disease.

4.1.2 Recent findings

Higher fibre intake was associated with a lower risk of type-2 diabetes mellitus in a Finnish cohort of 4,316 men and women (the Finnish Mobile Clinic Health Examination Survey), though the association was only borderline statistically

significant*.[33] The median fibre intake in the lowest quartile was 16 grams per day and in the highest quartile it was 40 g/day (3.0 grams per megajoule).

In a Finnish cross-sectional study conducted among family members of patients with type-2 diabetes mellitus who had not themselves had diabetes, higher dietary fibre intake was associated with lower insulin resistance (p=0.012), after adjustment for confounding variables.[34]

No association was found between total dietary fibre intake and the development of type-2 diabetes mellitus in the Nurses' Health Study II.[35]

It will be shown in section 4.2 that the consumption of whole-grain products probably has a protective effect against type-2 diabetes mellitus. Cereal fibre accounts for a far smaller share of total dietary fibre intake in the United States than in Finland. This might explain why an association between total dietary fibre intake and the risk of type-2 diabetes mellitus is found in Finnish studies, but not in US studies.

4.2 Effects of different dietary fibre types

*4.2.1 Specific types of dietary fibre***

The Institute of Medicine reviewed the effects of isolated types of dietary fibre on the rise in blood glucose concentrations after meals.[6] Its findings can be summarised as follows.

Strong evidence has been found in intervention studies to suggest that pectin, guar gum, inulin, psyllium, oat fibres and resistant maltodextrin reduce the rise in blood glucose concentrations after meals. Furthermore, guar gum, psyllium and oat fibres appear to improve sensitivity to insulin. In addition, glucose concentrations in 'fasting blood'*** may possibly be reduced by guar gum and fructo-oligosaccharides. Resistant starch appears to have a beneficial effect on the glycaemic index and may possibly reduce insulin secretion.

Cellulose has no effect on glucose response. The effect of chitin on glucose response has not been investigated.

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* Relative risk in the highest versus the lowest quartile of dietary fibre intake, after adjustment for confounding variables = 0.51; 95% confidence interval: 0.26 to 1.0.

** See Annex E.

*** Blood collected from people who have not eaten or drunk for several hours.

4.2.2 Categories of fibre: fibre from cereals, vegetables and fruit

Cereal fibre

There is evidence to suggest that consumption of whole-grain products provides protection against the development of type-2 diabetes mellitus.[36] In four cohort studies (the Finnish Mobile Clinic Health Examination Survey[33], the Health Professionals Study[37], the Nurses' Health Study I[38] and the Nurses' Health Study II[35]), a stronger association was discovered with the consumption of fibre from cereals than with total dietary fibre intake.

The available intervention studies with isolated cereal fibres do not support the findings from the cohort studies. The association that has been observed in observational research with cereal fibre should possibly be regarded as a marker for the protective effect of consuming plenty of whole-grain products.[39]

Fibre from vegetables and fruit

None of the available cohort studies produced any evidence of an association with the consumption of fibre from vegetables.[33,35,37,38] Only one of these four cohorts revealed an inverse association with the consumption of fibre from fruit.[35]

4.3 Conclusion

Although it has not been convincingly demonstrated that total fibre intake protects against the development of type-2 diabetes mellitus, there are fairly strong indications that whole-grain products exert a protective effect.

The role of dietary fibre in the treatment of type-2 diabetes mellitus is not discussed here, since the theoretical aim of this advisory report is to formulate a dietary reference intake for the healthy population. The Committee considers it sufficient to note that, based on the outcomes of meta-analyses of randomised intervention studies in patients with this disease, such patients are advised to eat a high-fibre diet (25 to 50 grams of fibre per day, or 3.6 to 6.0 grams per megajoule).[40]

Chapter 5

Overweight

Can fibre consumption have a positive effect on the prevention or limitation of overweight and obesity? Research results concerning this health issue must also be involved in considerations regarding the determination of a fibre consumption guideline.

5.1 Effects of total dietary fibre intake

5.1.1 Opinion of the Institute of Medicine

The Institute of Medicine described several observational studies in which overweight was more commonly observed in people with a low fibre intake. The Institute of Medicine also found that the results of intervention studies into the effect of dietary fibre intake on the feeling of satiety and on food intake were inconclusive. It is possible that dietary fibre may reduce energy intake only where intake is very high (more than 30 grams per meal). All things considered, the Institute of Medicine found insufficient evidence to base recommendations on the effect of fibre on hunger, satiety and weight control.[6]

5.1.2 *Recent findings*

In the advisory report Overweight and Obesity [*Overgewicht en obesitas*], the Health Council stated that an association had been found in prospective cohort research between higher dietary fibre intake and lower body fat percentage, whereas the results of experimental research into this association were less conclusive.[41] The report concluded that a high-fibre diet plays an important role in the prevention of overweight, but that it is not possible to set an optimal level of dietary fibre intake for weight regulation.

In the Health Professionals Follow-up Study, the weight gain recorded in men over eight years (after adjustment for various confounding variables) was 1.4 kilograms in the lowest quintile of fibre intake, compared with 0.39 kg in the highest quintile.[42] In the Nurses' Health Study, the increase in body weight was smallest in those subjects whose total fibre intake showed the greatest increase.[43] In this highest quintile, fibre intake had risen by 8.9 grams per day, compared with a decrease of 3.4 grams per day in the lowest quintile. Higher fibre intake was also found to correlate with lower average weight and a smaller increase in body weight in the Coronary Artery Risk Development in Young Adults Study (an American cohort of 2,909 adults monitored for ten years). [44] Although it was published in 1999, this study was not included in the Institute of Medicine report.

5.2 Effects of different dietary fibre types

5.2.1 *Specific types of dietary fibre*[*]

No evidence was found in one pilot study to suggest that the type of dietary fibre influences the effect on weight regulation. No differences in the effects on body weight were observed after subjects' diets were supplemented over a three-week period with 27 grams per day of fermentable fibre supplements (pectin and beta-glucans) or 27 g/day of non-fermentable fibre (methylcellulose) fibre supplements.[45]

5.2.2 *Categories of fibre: fibre from cereals*

In the Nurses' Health Study, the women with the highest intake of cereal fibre had the lowest body weight.[43] Such an inverse association between the consump-

* See Annex E.

tion of whole-grain products and body weight was also discovered in two other prospective cohort studies (the Iowa Women's Health Study and the Coronary Artery Risk Development in Young Adults Study).[46]

5.3 Conclusion

A high-fibre diet plays an important role in the prevention of overweight. However, it is not possible to quantify optimal intake on the basis of the available data. No conclusions can be drawn about specific types or categories of dietary fibre of because there is insufficient evidence that different types of fibre differently affect body weight.

Chapter 6

Cancer of the colon

It has been claimed that certain types of dietary fibre dilute or bind faecal carcinogens and reduce colonic transit time.[47] It is therefore plausible that dietary fibre may protect against colon cancer.

6.1 Effects of total dietary fibre intake

6.1.1 Opinion of the Institute of Medicine

The Institute of Medicine discussed the results of five intervention studies into the effect of dietary fibre intake on the development of colorectal adenomas.[48-52] Although the majority of adenomas do not progress to malignancy, they are nevertheless regarded as precursors of malignant tumours.

Dietary fibre did not exert a protective effect in any of the intervention studies. Indeed, one of the studies actually discovered an increase in risk upon supplementation with psyllium*.[50] This particular type of fibre was not used in the other four studies. In two studies, the habitual diet of the intervention group was supplemented with 12 and 11 grams per day, respectively, of fibre from wheat bran.[48,50] The intervention group in the third study followed a diet (after intensive counselling) that provided the men with 35 grams of dietary fibre a day and the women with 29 g/day. The men and women in the control group received 19 g and 16 g

* See Annex E.

per day, respectively.[51] In the fourth study intensive counselling in the intervention group resulted in a diet containing an average of 24% of total calories from fat and 4.2 grams of dietary fibre per megajoule, whereas the diet of the control group contained 34% of total calories from fat and 2.4 grams of dietary fibre per megajoule.[52]

The results of the cohort studies into the association between total dietary fibre intake and the risk of colorectal cancer are summarised in Table 4. There was no association between fibre intake and the incidence of colon cancer in two large cohort studies that were available to the Institute of Medicine (the cohort of American nurses [the Nurses' Health Study] and the cohort of Finnish male smokers who participated in the Alpha-Tocopherol, Beta-Carotene Cancer Prevention Study [the ATBC study]).[53,54] An association was, however, found between fibre intake and the risk of coronary heart disease in these cohorts. Thus, the quality of the data relating to fibre intake does not appear to be at issue.[19,21]

The Institute of Medicine could not provide a recommendation because it found the evidence that dietary fibre affects the risk of colon cancer to be insufficiently convincing.

6.1.2 *Recent findings*

The largest cohort study on this topic is the European Prospective Investigation into Cancer and Nutrition (EPIC). The EPIC investigators published articles on the association between dietary fibre intake and the risk of colorectal cancer in 2003 as well as in 2005.[16,55] Table 4 gives the results of the most recent analysis.[55] Due to a longer follow-up, this latter study identified considerably more cases of colorectal cancer (1,721 in 2005 compared with 1,065 in 2003). Furthermore, the adjustment for confounding variables was qualitatively better in this latter publication. The results suggested a dose-response relationship over the first four quintiles with lower risks of colorectal cancer when dietary fibre intake was higher. Risk was 21% lower in the second-highest and highest quintiles of fibre intake than in the lowest quintile. The risks in the second-highest and highest quintiles of dietary fibre intake were similar.

A new, combined analysis of the data from the Nurses' Health Study and the Health Professionals Follow-up Study has been conducted in response to the EPIC investigators' first article. The investigators wanted to examine the extent to which the difference between the research outcomes was attributable to the way in which adjustment was made for confounding variables.[15]

Using the limited adjustment procedure which had been used in the EPIC 2003 publication, dietary fibre was found to have a protective effect against colorectal

cancer in the pooled American cohorts. The risk decreased by 9% for each 5 g/day increase in total dietary fibre intake.* This association disappeared, however, when adjustment was made for more confounding variables.** Table 4 indicates the relative risk for the comparison of the highest with the lowest quintile.

In response to this American publication, the EPIC investigators conducted their renewed analysis in which they largely applied the more comprehensive American adjustment for confounding variables. The results outlined in the first paragraph of this section and in Table 4 are those from this improved analysis (published in 2005) and not the results of the original analysis (published in 2003). In the EPIC study, the adjustment for more confounding variables was found to have little effect on the study outcome.

In the Pooling Project of Prospective Studies of Diet and Cancer, the databases of 13 European and American cohort studies with a broad range of fibre intakes were combined to form a pool comprising 725,628 participants and 8,081 cases of colorectal cancer.[60] The EPIC study was not included in this pooled analysis. When adjustment was made for various confounding variables (including dietary folate), the quintile with the lowest fibre intake had an increased risk for developing colorectal cancer. In addition, the difference compared with the second and third quintile of fibre intake was statistically significant, whereas the difference compared with the fourth and fifth quintile was not. Table 4 gives the difference between the first and fifth quintiles. The study produced no evidence of a dose-effect relationship over the entire range of fibre intakes.

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* Using the simple correction procedure, the relative risk for a 5 g/day increase in total dietary fibre intake was 0.91 (95% confidence interval: 0.87 to 0.95). In this simple correction procedure, adjustments were made for the following confounders: age, height, weight, energy intake from fat and energy intake from sources other than fat.

** Using the comprehensive correction procedure, the relative risk for a 5 g/day increase in total dietary fibre intake was 0.99 (95% confidence interval: 0.95 to 1.04). In this comprehensive correction procedure, adjustments were made for the following confounders: age, time period, occurrence of colorectal cancer in family members, use of aspirin, the number of pack-years of smoking with onset in adolescence, the use of multi-vitamin supplements, energy intake from fat, energy intake from sources other than fat, alcohol use, dietary folate, red meat, meat products, calcium and methionine, glycaemic load, and (for women) menopause status and post-menopausal hormone use. The American investigators suspect that adjustment for dietary folate is extremely important (especially in populations using few supplements and fortified foods). This is because intake of both dietary folate and dietary fibre is mainly derived from fruit, vegetables and cereals.

Table 4 Results of prospective cohort studies into the effect of dietary fibre on colorectal cancer.

Publication	Cohort size	Years of follow-up
Institute of Medicine		
Nurses' Health Study[53]	88,757	16
Health Professionals Follow-up Study[56]	47,949	6
Finnish cohort[54]	21,930	8
More recent research		
European Prospective Investigation into Cancer and Nutrition (EPIC)[55]	519,978	6.2
Gecombineerde analyse van Nurses' Health Study (1984-2000) en Health Professionals Follow-up Study (1986-2000)[15]	124,226	16
Breast Cancer Detection Demonstration Project; BCDDP[57]	61,429	8.5
Pooling Project of Prospective Studies of Diet and Cancer[60] [c]	725,628	6 tot 20
Cancer Prevention Study II Nutrition Cohort[59]	133,163	4.5

a M = men; F = women

b The 'calibrated' intake data have been used here. In the lowest consumption category, the calibrated calibrated consumption data are somewhat lower than the uncalibrated data. The values of the other

c All of the cohorts featured in this table, except for EPIC, are included in this Pooling Project of

Number of cases	M/F [a]	Median fibre intake in grams per day (grams per megajoule)		Relative risk (95% confidence interval) for the highest versus lowest consumption category, adjusted for several confounding variables
		Lowest consumption category	Highest consumption category	
787	F	10	25	0.95 (0.73-1.25)
251	M	14	33	1.08 (0.68-1.70)
185	M	16 (1.4)	35 (3.1)	1.0 (0.6-1.5)
1,721	M/F	18.2/15.9[b]	30.1/24.3[b]	0.79 (0.63-0.99)
1,596	M/F	(<1.9)	(>3.3)	0.94 (0.74-1.20)
487	F	10 (1.7)	19 (4.0)	0.94 (0.70-1.26)
8,081	M/F	-	-	0.94 (0.86-1.03)
508	M	<9.3	≥16.6	0.92 (0.64-1.32)
	F	<8.0	≥14.4	0.86 (0.52-1.42)

values are somewhat higher than the uncalibrated values. In the highest consumption catecory, the studies in this table are comparable with the uncalibrated data.
Prospective Studies of Diet and Cancer[60].

In the Breast Cancer Detection Demonstration Project, no significant association was found between dietary fibre intake and the risk of colon cancer (see Table 4).[57]

Nor was an association discovered between the consumption of dietary fibre and the risk of colon cancer in the Cancer Prevention Study II Nutrition Cohort (see Table 4).[59]

Publication of the EPIC coincided with the release of the findings of a large case-control study of dietary fibre and colorectal adenomas, conducted as part of the Prostate, Lung, Colorectal, and Ovarian Cancer Screening Trial (PLCO).[61] In this study, 3,591 patients (men and women) with at least one adenoma were compared with 33,971 controls. The median of the total fibre intake was 13 grams per day (2.2 grams per megajoule) in the lowest quintile and 36 grams per day (3.1 grams per megajoule) in the highest quintile. This study pointed to a dose-response relationship whereby the group with the highest fibre intake had the lowest risk of adenomas. The odds ratio for the risk of colorectal adenomas was 0.73 (95% confidence interval: 0.62 to 0.86).

It is evident from the foregoing discussion that in the EPIC study the risk of colon cancer over the first four quintiles of dietary fibre intake decreased as dietary fibre intake increased. There was no difference in the EPIC study in risk between the two quintiles with the highest dietary fibre intake. In most of the other cohort studies, there was no association between dietary fibre intake and the development of colorectal cancer. In the Pooling Project of Prospective Studies of Diet and Cancer, which combines the results of the key cohort studies (except for EPIC), there was an increased risk in the lowest quintile of fibre intake, but without any apparent dose-response relationship.

The anomalous finding in the EPIC study cannot be explained either by differences in cohort size or by differences in the total fibre intakes in the highest consumption category (see Table 4). It is conceivable that part of the differences may stem from differences in the consumption of specific types of dietary fibre.

6.2 Effects of different dietary fibre types

The results of the Prostate, Lung, Colorectal, and Ovarian Cancer Screening Trial suggest that fibre from cereals and fruit, in particular, protect against the formation of adenomas. No association was identified for fibre from vegetables.[61] In this study, the 90th percentile* of the intake of fibre from cereals and fruit was 14 and 9 grams, respectively, per day.

Various other cohort studies showed no statistically significant association either with fibre from cereals or with vegetable or fruit fibre.[16,53,54]

In a Swedish cohort study, the increased risk was mainly found in the group with a very low intake of fibre from vegetables and fruit (relative risk 1.65 and 95% confidence interval 1.23 - 2.20). No association was observed for cereal fibre.[62] The effect of total dietary fibre intake on the development of colorectal cancer was not determined in this study.

It appeared from the combined analysis of the data from the Nurses' Health Study and the Health Professionals Follow-up Study that the intake of many types of fruit fibre was associated with a lower risk of colorectal cancer (the relative risk for each 5 g/day rise in intake was 0.89, with a 95% confidence interval of 0.80 to 1.00).[15] For cereal fibres, the risk was increased in the quintile with the lowest intake, though there was no apparent dose-response relationship. In addition, only the difference between the lowest and the second-lowest quintile of cereal-dietary fibre intake was statistically significant. No evidence was found to suggest that vegetable fibre has a protective effect.

In the EPIC study, high consumption of fruit fibre was associated with a lower risk of colorectal cancer. Risk was 19% lower in the highest quintile of fruit-fibre intake than in the lowest quintile (relative risk 0.81; 95% confidence interval: 0.68-0.97). There was evidence to suggest a protective effect against colorectal cancer for cereal fibre too, but that association disappeared after adjustment for all relevant confounding variables. In the EPIC study, the consumption of fibre from vegetables and legumes was not associated with a lower risk of colorectal cancer.

6.3 Conclusion

Dietary fibre has been found in a large case-control study to exert a dose-dependent protective effect against adenomas. However, none of the intervention studies showed fibre supplementation to have an effect on the formation of adenomas. Since the Committee attaches greatest importance to the results of the intervention studies, it concludes that dietary fibre intake probably has no effect on the formation of adenomas. The results of the intervention studies do not, however, provide any information about the effect of dietary fibre at a later stage of carcinogenesis.

* Explanation of the term 'percentile': i.e. dietary fibre intake is lower than the 90th percentile of fibre intake in 90% of the study population; dietary fibre intake is lower than the 50th percentile (the median) in 50% of the study population, etc.

Observational cohort studies indicate that very low dietary fibre intake (the lowest quintile of intake) is associated with an increased risk of colon cancer. The research results do not provide a consistent picture with regard to higher consumption levels.

The Committee concludes that there is insufficient evidence that total dietary fibre intake has a protective effect against colon cancer. High consumption of fruit fibre may possibly be associated with a lower risk of colon cancer.

Chapter 7

Derivation of the guideline

What guidelines should be set for dietary fibre intake in adults and in children if all factors are taken into consideration? And is it possible and necessary to set a tolerable upper intake level for dietary fibre intake? These are the key questions to be addressed in this final chapter.

7.1 Guideline for adults

7.1.1 Basis for the guideline

The effects considered

In the light of the research data presented in the preceding chapters, the Committee has decided to base the guideline for adults on two effects of dietary fibre, namely the effects on gut function and on coronary heart disease. The importance of dietary fibre intake for healthy gut function is evident from intervention research. The protective effect of a high-fibre diet against coronary heart disease is supported by results from both observational and intervention research. There would appear to be a dose-response relationship over the entire range of intakes.

Other possible effects

The preceding chapters show that the consumption of dietary fibre is also associated with effects that have not been taken into consideration in formulating the guideline. For example, it appears that dietary fibre may play a role in the prevention of overweight, but it is not possible to set an optimal level of intake for weight regulation. Furthermore, there are fairly strong indications that the consumption of ample whole-grain products provides protection against the development of type-2 diabetes. However, the guideline relates to total dietary fibre intake. Whether a high total dietary fibre intake is also protective against type-2 diabetes mellitus is less clear on the basis of the available research data. This possible effect has therefore not been taken into consideration during the derivation of the guideline. A very low dietary fibre intake is probably inadvisable as far as the risk of colon cancer is concerned. There is, however, insufficient scientific evidence that a high dietary fibre intake is necessary in order to prevent colon cancer.

7.1.2 Evidence base for beneficial effect on gut function

How has this guideline been derived from the effect on gut function (which was the first effect to be considered)? The consumption of dietary fibre increases faecal bulk. It is important that faecal bulk should exceed a certain critical level (160-200 grams), since lower faecal output is associated with a slower gastrointestinal transit. When faecal output exceeds 160-200 grams, intestinal transit virtually always takes place within two days. According to the available intervention studies, the critical faecal weight of 160-200 grams per day is attained with a dietary fibre intake of 32 to 45 grams per day (provided that the levels of fluid intake and physical activity are adequate, see section 2.3). This level of dietary fibre intake is important for the prevention of constipation (though constipation can also be caused by other factors).

7.1.3 Evidence base for protection against coronary heart disease

The second effect that has been taken into consideration during the derivation of the guideline is the protective effect against coronary heart disease. The available research indicates that a high-fibre diet helps to prevent coronary heart disease. A dose-response relationship has been identified over the entire range of fibre intakes in the observational studies. Since the subjects in these studies have been assigned fairly randomly to four or five groups in ascending order of fibre con-

sumption (quintiles), the choice of a single value as the optimal level of fibre intake is somewhat arbitrary.

The US Institute of Medicine has set an optimal fibre intake of 3.4 grams of dietary fibre per megajoule, or 14 grams of dietary fibre per 1,000 kilocalories. This value is based on the 90th percentile of intake in the three most relevant prospective cohort studies of the association between dietary fibre intake and the risk of coronary heart disease (two American studies and one Finnish study*). This means that 90% of the subjects ate less than 3.4 grams of fibre per megajoule. The 90th percentile value in the American studies was 3.4 and 3.5 grams per megajoule, and in the Finnish study it was 3.1 grams per megajoule. When expressed in grams per megajoule or kilocalorie, the values for men and women are very similar. Therefore the Institute of Medicine finds it unnecessary to differentiate by sex.

The Committee endorses the choice of the 90th percentile of fibre intake. It also supports the decision to set the optimal dietary fibre intake in grams per megajoule and not in grams per day, since people who eat more may also conceivably need more dietary fibre. Research published since the appearance of the Institute of Medicine advisory report gives the Committee no reason to change the value of 3.4 grams per megajoule. Nor, according to the Committee, do the five uncertainties outlined below constitute sufficient grounds to deviate from the value of 3.4 grams per megajoule.

1 In the cohort studies, fibre intake has been determined by means of a food frequency questionnaire, which gives rise to a wider range of fibre intakes in grams per day than more accurate methods (see section 1.4.2). In reality, the 90th percentile of fibre intake will therefore probably be somewhat lower than that measured in these studies. Owing to uncertainty over the extent of this effect, the Committee did not regard this as a sufficient reason to modify the value of 3.4 grams per megajoule.
2 The 90th percentile of dietary fibre intake in grams per day was relatively low in the American publications (23 g/day in the Nurses' Health Study, 29 g/day in the Health Professionals Follow-up Study and 21 g/day in NHANES), whereas these were actually the studies in which the highest value was found in grams per megajoule. This is because the American food frequency questionnaires do not effectively measure energy intake, since they were not

* The cohorts from the Alpha-Tocopherol, Beta-Carotene Cancer Prevention Study21, the Health Professionals Follow-up Study18 and the Nurses' Health Study19. These were studies with sufficient statistical power, the subjects had been divided into quintiles on the basis of dietary fibre intake, and energy intake was also reported in these studies.

designed for estimating energy intake. Annex F indicates that the 90th percentile of dietary fibre intake in grams per megajoule may well be somewhat lower among Dutch men aged 22 - 49 years than in the American studies (3.2 grams per megajoule), but that the 90th percentile in grams per day is substantially higher (35 grams per day). For Dutch women of the same age, the 90th percentile in grams per megajoule is the same as that in the US studies, but the 90th percentile in grams per day is considerably higher (3.5 grams per megajoule and 35 grams per day). The Committee did not regard this as a reason to adjust the value of the guideline.

3 The results of US research may possibly be more applicable to the Dutch situation than the results of Finnish research. This is because the AOAC method of dietary fibre analysis serves as the standard in the United States and the Netherlands, whereas in Finland the fibre content of foods is determined using the Englyst method, which produces a lower estimate than the AOAC method. This line of reasoning therefore supports the use of 3.4 grams per megajoule as the value for the Dutch guideline.

4 Research results concerning the effects of total dietary fibre intake from US studies may well be less applicable to the Dutch situation than the results of studies from other Northern European countries, since total fibre intake in the United States has a very different composition to that in Northern Europe. It is unclear whether this finding constitutes grounds for changing the value of 3.4 grams of dietary fibre per megajoule.

5 The fact that the guideline is based on the 90th percentile suggests that it is achievable. After all, ten percent of the study populations have at least that level of dietary fibre intake. However, this implicitly assumes that everybody is equally susceptible (or insusceptible) to potential adverse effects of high fibre intake such as abdominal cramping and flatulence. If susceptibility does, in fact, vary from one individual to another, then it is conceivable that the people in the highest intake category are a selection from the group of people that is relatively less susceptible to the adverse effects of high fibre intake. Owing to the speculative nature of this reasoning, however, the Committee must disregard this possibility here. Consequently, this also had no not influence the derivation of the intake value.

A further question posed by the Committee is whether the protection that a high-fibre diet affords against coronary heart disease is, in fact, attributable to dietary fibre, or whether there is another contributory factor. The findings are inconclusive.

Observational research indicates that a high total dietary fibre intake and a high fruit and cereal fibre intake are associated with a lower risk of coronary heart disease. This finding is supported by results of intervention studies that indicate that a few specific types of dietary fibre have beneficial effects on risk factors for cardiovascular disease. For example, the association between a high intake of fruit fibre and a lower risk of coronary heart disease is supported by the finding from intervention research that pectin, a type of fibre commonly found in fruit, has a beneficial effect on blood cholesterol levels.

Several studies have, however, raised doubts over whether the beneficial effects of a high intake of cereal fibres should, in fact, be ascribed to dietary fibre:

- The effect of rice bran on total and blood LDL cholesterol levels was found in an intervention study to be caused not by the dietary fibre fraction but by the oil fraction of this bran[63].
- Although oat bran and oat gum (both of which contain dietary fibre in the form of beta-glucans) have been found in intervention studies to have beneficial effects on blood lipids, such effects have not been identified upon supplementation with purified beta-glucans.[6]
- Although a higher intake of cereal fibre is associated with a lower risk of coronary heart disease and cellulose makes a significant contribution to cereal fibre intake, cellulose has not been found to have any beneficial effect on blood cholesterol levels in intervention studies. Indeed, cellulose actually led to a slight increase in cholesterol levels in some studies.[6]
- In an observational study, total mortality among women who consumed cereal fibre mostly from whole-grain products was lower than total mortality among women who consumed approximately the same amount of cereal fibre not from whole-grain products but from refined cereal products.[64]

Although the protective effect of whole-grain products against coronary heart disease might be mediated by a mechanism other than the concentrations of cholesterol fractions in the blood, the Committee concludes that it is unclear, on the basis of the available research, whether this effect is, in fact, due to dietary fibre. It is therefore uncertain whether the protective effect of whole-grain products against coronary heart disease would also be obtained by adding purified dietary fibre to low-fibre cereal products via supplements or through enrichment of foods. Consideration should also be given to the fact that the physiological effect of fibre-enriched products will, to a large extent, be determined by the type of dietary fibre with which the product is enriched. For example, one type of dietary

fibre may have an effect on risk factors for coronary heart disease whereas another may not.

It would appear from the above that the observed association between a high total dietary fibre intake and a low risk of coronary heart disease may possibly be only partially attributable to dietary fibre. The association can, however, probably be ascribed to the consumption of high-fibre products. The Committee therefore contends that the guideline is applicable to dietary fibre intake via a mixed diet consisting of products that have not been enriched with isolated and purified dietary fibre. The Committee emphasises the fact that it is issuing a guideline and not a dietary reference intake. This approach serves to underline the uncertainties that surround the specified value.

7.1.4 Guideline

In view of the effects of dietary fibre on gut function and on the risk of coronary heart disease, the Committee has set a guideline for dietary fibre intake for adults of 3.4 grams of dietary fibre per megajoule (one megajoule is equal to one thousand kilojoules), or 14 grams of dietary fibre per 1,000 kilocalories. This represents an increase in the guideline, which previously stood at 3.0 grams per megajoule (see Annex B). The guideline value for adults corresponds to the US adequate intake.

The guideline is applicable to dietary fibre intake via a mixed diet consisting of products that have not been enriched with isolated and purified dietary fibre. There is evidence to suggest that the use of whole-grain products and fibre from fruit, in particular, leads to a lower risk of coronary heart disease.

7.1.5 Indication of desirable dietary fibre intake in grams per day

To give an idea of desirable dietary fibre intake in grams per day, the guideline has been multiplied by the average energy intake in each group (Table 5). The table shows that when this guideline is applied, dietary fibre intake in grams per day lies within the range that is considered desirable for smooth intestinal transit (32 to 45 grams per day).

The amount of dietary fibre (in grams per day) indicated in the table is a group average. Energy intake varies markedly from one person to another. In order to calculate the desirable dietary fibre intake for a specific individual in grams per day, it is necessary to multiply the guideline by that person's energy intake. This value may be either higher or lower than the group average that has been given in Table 5.

Table 5 Indication of dietary fibre intake in grams per day, calculated by multiplying the average energy intake in the Netherlands in megajoules per day by 3.4 grams of dietary fibre per megajoule (14 grams per 1,000 kcal).

Group		Average energy intake in megajoules per day	Indication of optimal dietary fibre intake in grams per day[a,b,c]
Age	Sex		
19-0 years	men	11.4	40
	women	8.5	30
31-50 years	men	11.2	40
	women	8.5	30
51-70 years	men	10.1	35
	women	7.7	25
71 years and over	men	9.3	30
	women	7.5	25
pregnant women		+1.2	+5
lactating women		+2.1	+5

a The value given is an average for the group in question. The value for an individual may be higher or lower and is calculated by multiplying the guideline of 3.4 megajoules per day by that individual's energy intake.
b To avoid 'false accuracy', the values have been rounded to the nearest five grams per day.
c These amounts relate to the consumption of dietary fibre via plant-based foods that have not been enriched with fibre.

7.2 Guideline for children

7.2.1 Guideline

For children, the Committee has opted for a dietary fibre guideline that progressively increases with the age of the child as follows: 2.8 grams per megajoule for children aged 1 to 3 years, 3.0 grams per megajoule for the 4-8 year age group, 3.2 grams per megajoule for the 9-13 year age group, and the same value as for adults (3.4 grams per megajoule) for the 14-18 year age group. No dietary fibre guideline is set for babies in the first year of life.

7.2.2 Evidence base

The Institute of Medicine considered that the value of 3.4 grams of dietary fibre per megajoule (14 grams per 1,000 kilocalories) that is recommended for adults is also applicable to children aged one year and over. This value is, however, based on the protective effect against coronary heart disease in adults and on studies conducted to establish the effect of dietary fibre intake on intestinal transit time in adults. It is not known whether dietary fibre intake at a very young age has

any effect on the development of coronary heart disease at a later age. The Dutch Food Consumption Survey indicates that less than five percent of Dutch children consume 3.4 grams of fibre per megajoule (14 grams per 1000 kilocalories). It is conceivable that a high fibre intake could jeopardise energy intake in some children aged 1 to 3 years.[65]

In the light of the above considerations, the Committee opts for a guideline that progressively increases with the age of the child. Thus the guideline for 1-3 year-olds is set at the 90th percentile of intake in that group (2.8 grams per megajoule) and the guideline for 14-18 year-olds is on a par with the guideline for adults (3.4 grams per megajoule). If their fibre intake is progressively increased with age, then children gradually become accustomed to a high-fibre diet.

The Committee endorses the US Institute of Medicine's decision not to set a guideline for the first year of life owing to the lack of research data for this age group. It would be advisable to formulate a guideline for infants once more is known about the effects of dietary fibre in the first year of life.

7.2.3 *Indication of desirable fibre intake in grams per day*

Table 6 provides an indication of the desirable dietary fibre intake in grams per day. The amounts provided are group averages. In order to calculate the desirable dietary fibre intake for a specific individual in grams per day, it is necessary to multiply the guideline by that person's energy intake. This value may be either higher or lower than the group average given in the table.

Table 6 Indication of optimal dietary fibre intake for children in grams per day.

Age group	Average energy intake	Guideline in grams per megajoule	Indication of desirable intake in grams per day
Boys			
1-3 years	6.1	2.8	15
4-8 years	7.5	3.0	25
9-13 years	9.5	3.2	30
14-18 years	11.3	3.4	40
Girls			
1-3 years	5.4	2.8	15
4-8 years	7.0	3.0	20
9-13 years	8.4	3.2	25
14-18 years	8.9	3.4	30

7.3 Tolerable upper intake level

According to the Institute of Medicine, there is insufficient data available to set a tolerable upper intake level. A high intake of dietary fibre may reduce the bioavailability of minerals owing to the presence of phytate in high-fibre products. However, this effect is to a great extent offset by the usually high mineral content of the concerned products. A high intake of dietary fibre may also cause intestinal complaints, such as flatulence, gas formation and diarrhoea. However, these complaints are rarely, if ever, serious. Moreover, the consumption of high-fibre foods is self-limiting owing to their voluminous character. The effects on mineral bioavailability and intestinal complaints might well be a problem if a high fibre intake is achieved by the use of fibre supplements.

Owing to these considerations, the Committee endorses the Institute of Medicine's decision not to set a tolerable upper intake level.

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Annexes

Annex **A**

Historical overview of Dutch dietary reference intakes

1949 Publication of the first Dutch recommendations regarding appropriate intake levels for energy and nutrients, which were drawn up by the Food and Agricultural Policy Committee of the former Ministry of Agriculture, Fisheries and Food. This Committee was responsible for producing recommendations until 1959 and published several revisions and addenda.

1959 The task of revising recommendations concerning appropriate intake levels for energy and nutrients was subsequently entrusted to the Food and Nutrition Council's Committee on Dietary Reference Intakes. This Committee, whose composition changed over time, regularly checked its recommendations against the current level of knowledge, adjusting or expanding them, where necessary. Accordingly, the 1989 report entitled *Nederlandse Voedingsnormen* [Dietary Reference Intakes in the Netherlands] was drawn up on the basis of the scientific literature published up to 1987. A second edition of this report, published in 1992, updated the information on several nutrients with data from the period 1987-1991.

1995 The Food and Nutrition Council organised an international workshop on dietary reference intakes. The results of scientific research increasingly showed that certain nutrients, alongside other factors, have a protective effect against the development of chronic diseases. It is now accepted, for example, that calcium and vitamin D may play a role in the prevention of osteoporosis and bone fractures.

This is one of the reasons why it is considered necessary to revise the dietary reference intakes.

1996 The Food and Nutrition Council was abolished. Its duties, including the revision of the dietary reference intakes, were transferred to the Health Council.

1997 The President of the Health Council set up the Committee on Dietary Reference Intakes. This Committee has revised the dietary reference intakes for 14 nutrients and set down its findings in three advisory reports. The first report related to the dietary reference intakes for calcium, vitamin D, thiamine, riboflavin, niacin, pantothenic acid and biotin.[1] The second contained the dietary reference intakes for energy, proteins, fats and digestible carbohydrates.[2] The third advisory report dealt with vitamin B_{12} vitamin B_6 and folic acid.[3] The terminology, the mode of operation and the applications of the dietary reference intakes have been established by this Committee and form the first chapter of these three advisory reports. The Committee on Dietary Reference Intakes was abolished after the publication of the third advisory report, the intention being to continue the revision work with Committees created to review only one nutrient.

Annex **B**

Previous recommendations concerning dietary fibre

B.1 The Netherlands

The former Food and Nutrition Council produced a recommendation for the consumption of 3 grams per megajoule in 1992. [5] This recommendation was adopted from the 1986 *Richtlijnen Goede Voeding* [Guidelines for a Healthy Diet].[4] This report stated that: "We should probably be aiming to achieve an average intake of approximately 3 grams per megajoule of dietary fibre, rather than the present average of around 2.4 grams per megajoule."

B.2 Nordic countries

In 1996 the Nordic countries decided to recommend an intake of 3 grams per megajoule or 25-35 grams per day.[66]

B.3 German-speaking countries

In 2000 the German-speaking countries (Germany, Austria and Switzerland) recommended a fibre intake of 2.4 and 3.0 grams per megajoule for men and women, respectively.[67] They specified 3.0 grams per megajoule for children.

Annex **C**

The Committee

- Professor G Schaafsma
  nutritionist; TNO Nutrition and Food Research, Zeist
- Dr RA Bausch-Goldbohm
  nutritionist, epidemiologist; TNO Nutrition and Food Research, Zeist
- B Breedveld
  nutritionist; Netherlands Nutrition Centre, The Hague
- Dr EJM Feskens
  nutritionist, epidemiologist; Wageningen University and Research Centre (WUR), Wageningen
- Dr E Kampman
  nutritionist; epidemiologist, WUR, Wageningen
- Professor L Mathus-Vliegen
  gastroenterologist; Academic Medical Centre, Amsterdam
- Dr F Nagengast
  gastroenterologist; St Radboud University Medical Centre (UMC), Nijmegen
- Professor AGS Voragen
  food technologist; WUR, Wageningen
- B van der Heide, *adviser*
  Ministry of Health, Welfare and Sport, The Hague
- Dr LTJ Pijls, *secretary (until 1 January 2004)*
  Health Council of the Netherlands, The Hague

- Dr CJK Spaaij, *secretary (from 1 January 2004)*
  Health Council of the Netherlands, The Hague

The Health Council and interests

Members of Health Council Committees are appointed in a personal capacity because of their special expertise in the matters to be addressed. Nonetheless, it is precisely because of this expertise that they may also have interests. This in itself does not necessarily present an obstacle for membership of a Health Council Committee. Transparency regarding possible conflicts of interest is nonetheless important, both for the President and members of a Committee and for the President of the Health Council. On being invited to join a Committee, members are asked to submit a form detailing the functions they hold and any other material and immaterial interests which could be relevant for the Committee's work. It is the responsibility of the President of the Health Council to assess whether the interests indicated constitute grounds for non-appointment. An advisorship will then sometimes make it possible to exploit the expertise of the specialist involved. During the establishment meeting the declarations issued are discussed, so that all members of the Committee are aware of each other's possible interests.

Annex **D**

Comments on definitions of dietary fibre

D.1 Aspects of definitions of dietary fibre

All definitions of dietary fibre embrace some or all of the following aspects[68]:

Table 7 Aspects of definitions of dietary fibre.

Aspect	Examples or explanation
Source	Plant-based, synthetic.
Chemical character	Carbohydrates, polysaccharides, hydrophilic products of oligosaccharides and polysaccharides, lignin. The minimum degree of polymerisation of carbohydrates (usually 3) is often indicated when specifying chemical character.
Indigestibility in the small intestine	This aspect can give rise to uncertainties. For some substances, digestibility varies between individuals or with age.[69] Small children do not fully digest and absorb starch, lactose and fructose. Breast milk also contains substances that infants are unable to digest. [65] Some adults are unable to digest lactose.
Fermentability in the colon	
Method of analysis	
Physiological effects	

D.2 Institute of Medicine

The US Institute of Medicine (IOM) distinguishes between Dietary Fibre and Functional Fibre, and refers to the sum of these as Total Fibre.[70]

- *Dietary Fibre* consists of nondigestible carbohydrates and lignin that are intrinsic and intact in plants
- *Functional Fibre* consists of isolated, nondigestible carbohydrates that have beneficial physiological effects in humans
- *Total Fibre* is the sum of *Dietary Fibre* and *Functional Fibre.*

The reason why the IOM provided the definition of dietary fibre is, it explained, because it is difficult in epidemiological research to specifically ascribe a physiological effect to the fibre component of high-fibre foods on account of the many other substances that are present in these foods. Research with isolated nondigestible carbohydrates may well result in conclusions being drawn about fibre. The upshot of these definitions is that naturally occurring cellulose or inulin is regarded as dietary fibre, whereas added cellulose or inulin is regarded as functional fibre. The adopted terminology has provoked critical reactions, since the implication appears to be that 'dietary fibre' is not functional.[71]

D.3 American Association of Cereal Chemists (AACC)

The American Association of Cereal Chemists (AACC) decided on the following definition in 2000:

Dietary fibre is the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine. Dietary fibre includes polysaccharides, oligosaccharides, lignin, and associated plant substances. Dietary fibres promote beneficial physiological effects including laxation, and/or blood cholesterol attenuation, and/or blood glucose attenuation.[72,73]

The AACC explains that the references to the plant-based character of fibre and the substances associated with lignin in the definition were supported by a majority, but not all, of the involved parties. The list of physiological effects may be expanded in the future, if necessary.[73,74]

D.4 Food Standards Australia New Zealand

In Australia and New Zealand, Food Standards Australia New Zealand (FSANZ, formerly known as ANZFA) has recently produced a revised definition of dietary fibre [75]:

The edible parts of plants (or extracts or synthetic analogues of plants) that are not digested or absorbed in the small intestine, and that are usually completely or partially fermented in the colon. These also lead to one or more beneficial physiological effects, such as laxation or a reduction in the serum concentrations of cholesterol or glucose. Finally, the definition includes oligosaccharides consisting of more than two monosaccharides, polysaccharides and lignin

D.5 Codex Alimentarius

The Codex Alimentarius Committee on Nutrition and Foods for Special Dietary Uses discussed nutrition claims (e.g. 'rich in…', 'source of...') with regard to fibre in November 2003. A drafting group had previously formulated a definition of dietary fibre and proposed the most appropriate method of analysis, with input from the UK, the Netherlands and Sweden.[68] This subsequently formed the basis for a review article[69] This definition was then presented, with a few modifications, to the Codex Committee on Nutrition and Foods for Special Dietary Uses.[76,77] However, this Committee has as yet been unable to reach a consensus about the definition.[78]

Annex **E**

Sources of specific types of dietary fibre

The following list shows that several types of dietary fibre have been present in the Dutch diet for many years: beta-glucans, cellulose, fructo-oligosaccharides, hemi-cellulose, inulin, pectin, resistant starch, and also, to a limited extent, galacto-oligosaccharides. A number of other types of dietary fibre can appear in foods as additives (though not in the Netherlands, in some cases), examples being chitin, guar gum, polydextrose and psyllium.

Beta-glucans
: Sources of beta-glucans include oats and barley, but they are also found in many varieties of fungi and in all kinds of micro-organisms (e.g. yeasts).

Cellulose
: Cellulose is an important component of the cell wall of plants.

Chitin
: Chitin is marketed as a supplement in the United States and is obtained from the exoskeletons of lobsters, crabs and shrimps.

Fructo-oligosaccharides
: Found in products that also contain inulin, such as onions, wheat, bananas, leeks and tomatoes.

Galacto-oligosaccharides
: Found in certain types of yoghurt and (at low concentrations) in breast milk.

Guar gum

Guar gum is a food additive that is used as a stabiliser and thickening agent (E 412). It is obtained from the seeds of the guar plant.

Hemi-cellulose

Hemi-cellulose is found in the cell wall of plants.

Inulin

Inulin is found in plants such as onions, wheat, bananas, leeks and tomatoes and in the roots of chicory, scorzonera, artichoke, etc. It is used as a food additive (e.g. to make low-fat products taste creamier).

Pectin

Pectin is a type of dietary fibre widely found in fruit (e.g. quinces, apples and citrus fruits). This food additive is also used as a thickening agent (E 440a).

Polydextrose

Polydextrose is a food additive that is used as a thickening and bulking agent (E 1200).

Psyllium

Psyllium is a food additive that is used as a thickening agent. It contains glycosides and mucilages. It is obtained from the seed husks of Plantago psyllium or Plantago ovata and is also referred to as ispaghula husk.

Resistant starch

Sources of resistant starch include bread, cornflakes and cooked and cooled potatoes, rice and pasta.

Annex **F**

Dietary fibre intake in the Netherlands

Average intakes of dietary fibre in grams per megajoule (Table 8) and in grams per day (Table 9) can be found in the pages that follow. The figures given are based on the un-weighed averages of the intake on two days, as determined in the 1998 Dutch National Food Consumption Survey[79] or in the National Food Consumption Survey for 2003 [80]. The 2003 survey only included the age group 19-30 years.

Table 8 Dietary fibre intake in the Netherlands in grams per megajoule.

Group	Average ± standard deviation	Minimum	Percentiles[a]					Maximum
			P5	P10	P50	P90	P95	
Boys/men								
1-3 years[79]	2.0 ± 0.6	0.9	1.2	1.3	1.9	2.8	3.1	3.7
4-6 years[79]	2.0 ± 0.6	0.6	1.0	1.2	1.9	2.8	3.0	3.6
7-9 years[79]	2.0 ± 0.6	0.8	1.2	1.4	2.0	2.8	3.0	3.4
10-12 years[79]	2.1 ± 0.6	0.6	1.1	1.4	2.0	2.9	3.1	3.5
13-15 years[79]	2.0 ± 0.5	0.9	1.0	1.4	2.0	2.6	3.0	3.6
16-18 years[79]	2.1 ± 0.7	0.4	1.0	1.2	2.0	2.9	3.3	4.6
19-21 years[79]	2.0 ± 0.7	0.2	1.0	1.1	2.0	2.8	3.2	3.8
19-30 years[80]	2.0 ± 0.5		1.2	1.4	2.0	2.7	2.9	
22-49 years[79]	2.2 ± 0.8	0.6	1.1	1.3	2.1	3.2	3.6	6.0
50-64 years[79]	2.5 ± 0.8	0.0	1.3	1.5	2.4	3.5	4.0	5.9
> 65 years[79]	2.6 ± 0.9	0.8	1.3	1.6	2.4	3.5	4.0	7.3
> 75 years[79]	2.8 ± 1.1	1.0	1.6	1.8	2.6	3.9	4.7	7.9
Girls/women								
1-3 years[79]	2.1 ± 0.7	0.9	1.1	1.3	2.1	2.9	3.2	5.6
4-6 years[79]	2.0 ± 0.6	0.9	1.2	1.3	2.0	2.9	3.0	5.3
7-9 years[79]	1.9 ± 0.5	0.9	1.2	1.3	2.0	2.7	2.8	3.3
10-12 years[79]	2.0 ± 0.6	0.7	1.2	1.2	1.9	2.8	3.0	3.6
13-15 years[79]	2.1 ± 0.7	0.9	1.1	1.2	2.0	2.9	3.3	3.8
16-18 years[79]	2.1 ± 0.7	0.6	1.1	1.2	2.1	3.2	3.6	4.4
19-21 years[79]	2.2 ± 0.8	0.8	1.1	1.3	2.1	3.6	4.0	5.2
19-30 year[80]	2.2 ± 0.6		1.3	1.5	2.1	3.0	3.3	
22-49 years[79]	2.4 ± 0.8	0.7	1.3	1.5	2.3	3.5	4.0	7.5
50-64 years[79]	2.8 ± 1.0	1.1	1.4	1.7	2.7	4.0	4.5	7.6
> 65 years[79]	2.8 ± 0.8	1.3	1.7	1.8	2.7	4.1	4.3	6.5
> 75 years[79]	2.8 ± 0.8	0.9	1.6	1.8	2.7	3.8	4.1	6.4
Pregnant[79]	2.2 ± 0.6	1.0	1.3	1.4	2.2	3.1	3.3	3.5

[a] See footnote on the next page.

Table 9 Dietary fibre intake in the Netherlands in grams per day.

Group	Average ± standard deviation	Minimum	Percentiles[a]					Maximum
			P5	P10	P50	P90	P95	
Boys/men								
1-3 years[79]	12 ± 4	4	6	8	11	17	19	25
4-6 years[79]	14 ± 4	3	7	8	13	20	20	27
7-9 years[79]	17 ± 6	5	9	11	17	23	25	39
10-12 years[79]	19 ± 6	6	10	11	19	27	29	36
13-15 years[79]	22 ± 7	7	11	12	21	32	34	50
16-18 years[79]	24 ±11	2	8	11	22	38	42	55
19-21 years[79]	24 ±10	0	9	12	23	41	45	55
19-30 years[80]	23 ± 6		14	15	22	31	33	
22-49 years[79]	24 ± 9	2	12	14	23	35	40	71
50-64 years[79]	25 ± 9	0	13	15	25	37	40	55
> 65 years[79]	24 ±10	4	12	13	23	36	40	80
> 75 years[79]	25 ±10	9	14	16	22	35	43	75
Girls/women								
1-3 years[79]	11 ± 4	2	5	6	11	16	18	24
4-6 years[79]	13 ± 4	5	7	8	13	18	20	27
7-9 years[79]	15 ± 5	6	7	8	14	21	23	24
10-12 years[79]	17 ± 6	3	9	10	16	24	28	31
13-15 years[79]	18 ± 6	5	9	10	18	26	30	37
16-18 years[79]	19 ± 7	4	8	10	19	28	30	34
19-21 years[79]	19 ± 7	1	8	11	19	26	31	39
19-30 years[80]	17 ± 5		10	11	17	23	25	
22-49 years[79]	20 ± 7	2	10	12	19	29	31	61
50-64 years[79]	21 ± 8	5	11	12	20	31	35	71
> 65 years[79]	21 ± 6	6	11	13	21	29	33	43
> 75 years[79]	20 ± 7	8	11	13	19	30	33	51
Pregnant[79]	20 ± 8	5	11	12	19	28	31	48

[a] Explanation of the percentiles: in 90% of the study population dietary fibre, intake is lower than the 90th percentile of fibre intake; in 50% of the study population, intake is lower than the 50ste percentile (the median), etc.