The Role of Dietary Fiber in Childhood and Its Applications in Pediatric Gastroenterology

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Introduction

Since the 1970s the importance of dietary fiber for human health has been acknowledged and investigated. In the 1970s a relation was found for the first time between constipation, hemorrhoids and fiber-depleted food. The term dietary fiber is familiar to most people, although many do not fully understand the nature of dietary fiber and its role in the diet. Dietary fiber is a normal constituent of healthy food. Both in enteral and oral feeding the presence of fiber is necessary; not only in the face of problems like constipation and encopresis but also for a wide range of other disorders in adults and children such as diabetes mellitus, hypercholesterolemia, high blood pressure and colon cancer. In this chapter we will review the nomenclature, physiological properties and fate of fiber in man and its applications in pediatric gastroenterology [1]. The role of fiber in colorectal neoplasia will not be discussed here.

Definition

Since Hipsley [2] introduced the term dietary fiber in 1953, the exact definition has been controversial as scientists have studied various aspects of the impact of food supply and dietary fibers upon health. Two important questions arise when a definition for dietary fiber is sought: first which polymers should be categorized as dietary fiber? And secondly, can the term
‘fiber’ be correctly assigned to substances that are not metabolized, and are also not fibrous in chemical structure. Here we will adopt the definition for dietary fiber as put forward by the Dietary Fiber Definition Committee of the American Association of Cereal Chemists [3]: ‘Dietary fiber is the edible part 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 fiber includes polysaccharides, oligosaccharides, lignin, and associated plant substances. Dietary fibers promote beneficial physiological effects including laxation, and/or blood cholesterol attenuation and/or blood glucose attenuation.’ However, this focus on digestibility has been contested in Europe [4]. There is no proof that digestibility is beneficial. Having a definition on the percentage of non-starch polysaccharide content of natural foods in food tables better serves the potential benefits of these plant cell walls (table 1).

According to the American definition, food components having the above properties can also be taken as dietary fibers such as resistant starch and non-digestible oligosaccharides. Resistant starch is the sum of starch and starch-degradation products not absorbed in the stomach and small intestine. Three types can be separated: RS1, physical non-approachable starch (lentils, beans); RS2, ungelatinized starch (bananas and potatoes), and RS3, retrograded starch (mainly amylose). These RS fibers are fermented at different rates in the colon and the amount in food is dependable on food production (heating and cooling down) [5, 6]. Legumes appear to be the single most important source of resistant starch, with as much as 35% of legume starch escaping digestion [7].

Non-digestible oligosaccharides are naturally present in food, mostly in fruits, vegetables or grains, or produced by biosynthesis from natural sugars or polysaccharides and added to food products because of their nutritional properties [8]. They consist mainly of fructo-oligosaccharides (FOS; one glucose molecule connected to as many as 60 fructose molecules or fructose molecules alone; the bond is of the \(\beta_{(2-1)}\) type). In nature these are mainly found in inulin, a mixture of FOS that can be turned into a mixture of FOS of 8 units by hydrolysis. If the fructose molecule is exchanged by a galactose molecule then galacto-oligosaccharides (GOS) occur. The latter are found in soybeans. GOS can also be synthesized from lactulose. FOS and GOS can be obtained quite pure and can be added to food as functional ingredients.

Today both FOS and GOS are also recognized as prebiotics. Prebiotics beneficially affect the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon. Recent data indicated that a prebiotic mixture of FOS and GOS was able to stimulate the development of a microbial flora similar to that of breastfed infants [9]. The authors suggested that prebiotics might play a role as modulators of the postnatal development of the immune system. Furthermore the GOS/FOS mixture significantly increased the number of bifidobacteria and reduced the number of pathogens in term as
well as in preterm infants when compared with a group of infants fed a formula without supplement [10]. Stool consistency and fecal pH were also positively affected. These data were confirmed in a double-blind randomized controlled study in infants comparing a FOS-supplemented cereal (0.75 g FOS/cereal) with placebo [11]. The FOS-supplemented cereal was well tolerated and improved stool regularity and consistency.

### Table 1. Dietary fiber content of foods (g/serving)

<table>
<thead>
<tr>
<th>Food groups</th>
<th>Food</th>
<th>Serving size</th>
<th>Total dietary fiber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruits</td>
<td>Apple, large with skin</td>
<td>1 apple</td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td>Banana</td>
<td>1 banana</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td>Figs, dried</td>
<td>2 figs</td>
<td>4.6</td>
</tr>
<tr>
<td></td>
<td>Orange</td>
<td>1 orange</td>
<td>3.1</td>
</tr>
<tr>
<td></td>
<td>Peach, canned</td>
<td>1/2</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>Pear</td>
<td>1 pear</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>Prunes, dried</td>
<td>5</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>Raisins</td>
<td>1 miniature box (14 g)</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>Strawberries, raw</td>
<td>1 cup, sliced</td>
<td>3.8</td>
</tr>
<tr>
<td>Vegetables</td>
<td>Beans, kidney, canned</td>
<td>1/2 cup</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>Broccoli, raw</td>
<td>1/2 cup</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>Brussels sprouts, cooked</td>
<td>1/2 cup</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>Carrots, raw</td>
<td>1/2 cup</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>Celery, raw</td>
<td>1/2 cup</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Lentils, cooked</td>
<td>1/2 cup</td>
<td>7.8</td>
</tr>
<tr>
<td></td>
<td>Lettuce, iceberg</td>
<td>1 cup, shredded</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>Peas, green, canned</td>
<td>1/2 cup</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>Peas, split, cooked</td>
<td>1/2 cup</td>
<td>8.1</td>
</tr>
<tr>
<td></td>
<td>Potatoes, boiled</td>
<td>1/2 cup</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>Spinach, cooked</td>
<td>1/2 cup</td>
<td>2.2</td>
</tr>
<tr>
<td>Grains</td>
<td>Bread, white, wheat</td>
<td>1 slice</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>Bread, whole wheat</td>
<td>1 slice</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td>Cheerios</td>
<td>1 cup</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td>Crackers, graham</td>
<td>2 squares</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>Cream of wheat</td>
<td>1 cup</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
<td>Oat bran muffin</td>
<td>1 muffin</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td>Oatmeal, cooked</td>
<td>3/4 cup</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>Raisin bran</td>
<td>1 cup</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>Rice, brown, cooked</td>
<td>1 cup</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>Rye crisp bread</td>
<td>1 wafer</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>Shredded wheat</td>
<td>2 biscuits</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>Wheat bran flakes</td>
<td>3/4 cup</td>
<td>4.6</td>
</tr>
<tr>
<td>Other</td>
<td>Apple pie</td>
<td>1 piece</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td>Chocolate cake</td>
<td>1 slice</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>Nuts, mixed, dry roast</td>
<td>28 g</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td>Yellow cake</td>
<td>1 slice</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Source: USDA Nutrient Database for Standard Reference.
It has to be addressed that the effect of prebiotics is only temporary and strictly related to intake. More research is needed to delineate optimal fiber intake for infants and children <2 years of age, the quantity and types of fiber that would be most appropriate, and if prebiotic supplementation leads to measurable long- and short-term benefits for infants.

**Table 2. Function of non-fermentable dietary fibers**

<table>
<thead>
<tr>
<th>Function</th>
</tr>
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<tbody>
<tr>
<td>Non-fermentable dietary fibers are hardly digested in the colon but still have important functions such as:</td>
</tr>
<tr>
<td>• Shortening the transit time</td>
</tr>
<tr>
<td>• Fluid uptake, feces content increase and softer stools</td>
</tr>
<tr>
<td>• Positive effect on gut integrity by trophic effects on colonic mucosa (increase in cell turnover and secretion of gut hormones)</td>
</tr>
</tbody>
</table>

The Effect of Dietary Fiber on Gastrointestinal Function

The effect of dietary fiber on the gastrointestinal tract is explained by its osmotic properties, its stimulating effect on intestinal motility and the water-retaining capacity in the intestine (table 2). The water-retaining capacity of crude fibers is greater than that of fine fibers, and raw fibers have better laxative effects than cooked ones. Insoluble fibers such as cellulose and lignin are minimally degraded by colonic bacteria and thereby retain water, increase fecal bulk and decrease the intestinal transit time [12]. Soluble fibers such as hemicellulose and pectin are largely broken down by the colonic microflora. They have little effect on fecal weight, but they increase fecal volume and soften the stool by increasing the bacterial mass [13].

Dietary fibers are also able to bind bile salts and fatty acids in the small intestine. They are liberated in the colon after fermentation of fiber and thereby have a laxative effect. Moreover, during fermentation of polysaccharides, gas and short-chain fatty acids (SCFAs) are produced. The predominant acids include acetate, propionate and butyrate. The production of SCFAs through fermentation of oligosaccharides by colonic flora is important because the SCFAs have well-described effects in the intestinal tract. For example, it is largely accepted that butyrate has an essential role in maintaining the metabolism, proliferation and differentiation of the different epithelial cell types [14]. Although, it has to be admitted that, despite its prominent role, the taxonomy, population structure, and dynamics of predominant butyrate-producing bacteria in the human intestinal tract are poorly understood [15]. Current research is focussed on developing new...
probes such as the 16S rRNA-targeted oligonucleotide probe to investigate the quantitative and qualitative distribution of bacteria in the gastrointestinal tract [15]. However, even experience with this new probe could not detect bacteria in all fecal samples further emphasizing the diversity of the colonic microbiota at the strain level. Future research probably will find inter-individual differences possibly due to diet, genetic constitution or geographic location.

**Fiber Intake Recommendations**

The amount of fiber needed by children varies by the age and weight of the child. The first recommendations about fiber intake were given by the American Academy of Pediatrics published in 1981. The revised recommendations were published in 1994 and 1995 and were based on the age of the child, health benefits such as controlling or preventing obesity, hyperlipidemia, diabetes and colon carcinoma and safety concerns [16]. In both European and American studies children consume amounts of fiber that are inadequate for health promotion and disease prevention [17–19]. Therefore, the American Health Foundation and the American Academy of Pediatrics recommends a minimal intake for children and adolescents 3–20 years of age to be equivalent to the age of the child plus 5 g of dietary fiber/day (age + 5). The age + 5 g level of fiber intake for children is similar to the American Academy of Pediatrics recommendation (0.5 g/kg/day) up to the age of 10 years, but lower for older adolescents. Furthermore, this recommendation is consistent with current guidelines for adult dietary fiber intake (25–35 g/day).

The current concern about recommending a high-fiber diet is that it has the potential for reduced energy density, reduced calorie intake, and poor growth, especially in very young infants. Secondary to these factors is the concern that such diets reduce the bioavailability of iron, calcium, magnesium and zinc. However, most investigators nowadays state that when dietary fiber intake is according to the recommendations given above and the dietary fiber is consumed within a proper balanced diet, mineral deficiencies will be of no real concern [16].

Despite the availability of fiber supplements it is sometimes difficult to achieve the recommended fiber intake. Especially constipated children are often trapped in a vicious circle of poor appetite resulting in poor intake. Moreover, side effects such as intolerance, ineffectiveness and tastelessness of the fiber product may lead to poor compliance of ingesting adequate fiber.

Despite the good intentions of the parents and advice by their primary care physicians, only half of the children receive the recommended amounts of dietary fiber [17]. Further public education with regard to fiber intake is warranted.
**Constipation**

When healthy volunteers add fiber to their diet, such as cereal brans, psyllium seed husk, methylcellulose or a mixed high-fiber cereal, stool weight increased and gastrointestinal transit time decreased. The increase in stool weight is caused by the presence of the fiber, by the water content of the fiber and by partial fermentation of the fiber which increases the amount of bacteria in stool. Already in 1927 a publication in the *American Journal of Physiology* suggested the laxative action of wheat bran [20]. Since then many papers have emerged in which a possible association is suggested between fiber intake and motility disorders. However, the association between fiber intake and constipation is still controversial [21]. To date, there are no large randomized clinical trials that have addressed the role of fiber in the treatment of constipation in otherwise healthy children.

Two case-control studies in children showed a lower fiber intake in constipated children compared to healthy controls [22, 23]. Discriminant analysis showed that only fiber intake was independently correlated with constipation [22]. On the other hand, it has been demonstrated that constipated children do generally not consume less fiber than healthy persons and treatment with increased fiber intake did not result in large clinical effects [18, 24–27]. Side effects such as intolerance and tastelessness of the fiber product may lead to poor compliance. Moreover, in the studies by Guimaraes et al. [26] and Mooren et al. [18], no correlation was found between dietary fiber intake and transit time in each of the colonic segments studied. Those children with prolonged colonic transit time did not differ in fiber intake compared with the group of children with normal colonic transit time. Surprisingly, patients with a fiber intake below the recommended levels had a shorter right, left and total colonic transit time (although not reaching statistically significant levels) than those with adequate fiber intakes.

Recently, two small double-blind placebo-controlled trials in 20 neurologically impaired constipated children and in 31 otherwise healthy constipated children showed the beneficial effects of glucomannan (a fiber gel polysaccharide from the tubers of the Japanese Konjac plant that has no unpleasant taste or smell) 100 mg/kg body weight (maximum 5 g/day) on defecation frequency, stool consistency, soiling episodes, suppository use and side effects [25, 27]. Although the defecation frequency significantly increased after glucomannan intake no correlation between fiber intake and transit time was shown. Tse et al. [28] documented a very low fiber intake of 2 g/day in children (3–17 years) with severe developmental disabilities living in residential institutions. By increasing fiber intake to 17 g/day relief of constipation and a significant reduction in the use of laxatives was achieved. A further increase in fiber intake to 21 g/day showed a further reduction in the use of laxatives. Although the authors suggest continuing to recommend increasing the fiber intake in children with constipation, larger clinical trials are needed to confirm
the outcome of these studies. In contrast to the studies by Staiano et al. [27] and Loening Baucke et al. [25], in a small randomized double-blind clinical trial (n = 30) Motta et al. [29] in Brazil showed no positive effect on treatment outcome and gastrointestinal transit time of soya polysaccharide fiber (10–20 g/day) in children with chronic constipation.

**Diarrhea**

Diarrheal disease is one of the two main causes of death in children in developing countries, claiming the lives of more than 3 million children every year [30]. Although standard glucose-based oral rehydration therapy corrects the dehydration caused by cholera, it does not reduce the diarrhea. SCFAs, which are produced in the colon from non-absorbed carbohydrates, enhance sodium absorption. In a beautiful randomized controlled trial Ramakrishna et al. [31] showed that 50 g of high-amylose maize starch, an amylase-resistant starch, per liter of oral rehydration solution significantly lowered diarrheal output compared to the standard oral rehydration therapy in 48 adolescents and adults with cholera. Furthermore, the mean duration of diarrhea was significantly shorter in the amylase-resistant starch group than in the conventional treatment group.

Recently, a significant clinical improvement in diarrhea was described in an 11-year-old patient affected by congenital chloride diarrhea after oral butyrate intake at a dose of 100 mg/kg/day [32]. As already discussed above, SCFAs have a great capacity for stimulating ion and water absorption; they provide energy and induce a trophic effect on both colonic and small bowel mucosa. Moreover, it has been shown that SCFAs, particularly butyrate, are avidly absorbed by the intestinal mucosa and that this process is responsible for the transport of Na⁺ and Cl⁻ through different mechanisms, primarily by the stimulation of an electro-neutral NaCl absorptive mechanism activated by parallel Cl⁻/butyrate and Na⁺/H⁺ exchanger and secondarily by upregulation of the Na⁺/H⁺ and Cl⁻/HCO₃⁻ exchangers [33]. Finally, butyrate is able to limit Cl⁻ secretion, inhibiting the Na⁺-K⁺-2Cl⁻ cotransporter activity.

**Cystic Fibrosis**

Patients with cystic fibrosis (CF) often have gastrointestinal complaints. Atypical abdominal pain, constipation, and obstruction from inspissated intestinal contents in the terminal ileum (distal intestinal obstruction syndrome, DIOS) are frequent complications. Slowing of intestinal transit secondary to persistent steatorrhea is believed to play a role. Gavin et al. [34] compared the mean daily intake of fibers in 28 children with CF and compared their data with 28 age-matched controls. The mean daily fiber intake in CF
children was significantly lower compared to healthy controls. Furthermore, they found that the mean fiber intake in children with moderate or severe abdominal pain was significantly lower than children with occasional but mild symptoms. The authors suggested that abdominal complaints and DIOS might be secondary to the low dietary fiber content in the diet of patients with CF. In contrast, in Belgian children with CF no relation was found between fiber intake and gastrointestinal complaints or DIOS [35]. The overall intake of fiber was adequate in this group of CF children. Further studies are needed to evaluate the need of dietary fiber in this specific group of patients.

**Appendicitis in Children**

It has been postulated that acute appendicitis is a serious disease to emerge with the adoption of fiber-depleted diets. In order to investigate the possible role of fiber in the etiology of acute appendicitis, Adamidis et al. [36] studied 203 consecutive appendectomized children with histologically proved appendicitis and 1,922 controls using the diet history method. This Greek group of researchers found that appendectomized children had a statistically significant lower mean daily intake of fiber (17.4 vs. 20.4 g, p < 0.001) including all fiber fractions: cellulose, pentose, exose and lignin. No statistical significant difference was found for energy, protein, carbohydrate and fat intake. Discriminant analysis proved that only cellulose and exose were independently correlated to appendicitis and lower fiber intake was thought to be the cause in 70% of the cases. Their results suggest that low fiber intake might play an important role in the pathogenesis of appendicitis. In contrast, Naaeder and Archampong [37] in their (much smaller) study of 173 children and adults did not find a correlation between dietary fiber intake and appendicitis. It is clear that more studies are needed to clarify the exact role of fibers and its relation with acute appendicitis, but it exemplifies the importance of sufficient fiber intake in children.

**Irritable Bowel Syndrome**

The main aim of dietary intervention in irritable bowel syndrome (IBS) is to manipulate colonic fermentation. High-fiber diets have long been used in adults with IBS but no studies exist in children with IBS. As fibers decrease the whole gut transit time, fiber-enriched diets may be more useful in the subgroup of children with IBS and constipation. Hammonds and Whorwell [38] examined the outcome of 13 trials in which fiber was used to supplement the diet of IBS patients. Only one 1 of 6 studies using bran reported an improvement in symptoms. The outcome of their survey was that the role of fibers is limited to those patients whose problem is predominantly constipation.
In patients with IBS and symptoms such as bloating, diarrhea and flatulence, low fiber or exclusion diets are the treatment of choice. Response rates of between 50 and 70% have been reported [39].

**Conclusion**

Fiber likely plays a valuable role both in the prevention and treatment of several gastrointestinal disorders. However, there is an obvious need for large clinical trials to test the efficacy and safety of fiber as a therapeutic agent in the clinical treatment of children with constipation, diarrhea, IBS and acute appendicitis.

**References**

Fibers in Childhood


Discussion

Dr. Aggett: Can I ask you to comment because I think one of the biggest problems concerning fibers is that no one knows what they are. You gave us a definition, but when it comes to labeling food, planning diets, giving recommendations, anticipating what the outcomes may be of manipulating so-called fiber intakes, etc., there is very little awareness of the sensitivity of what the components of fiber are actually doing or how one can actually measure them. As far as I know there are something like 3 or 4 different accepted ways to measure fiber for the sake of labeling foods. There is now a standardized approach within the European Union even though it is not necessarily accepted with enthusiasm amongst the constituent members. You gave reference to the ESPGAN Committee on Nutrition commentary on fibers, and one of the main points behind getting that report drafted was the comments and concerns that I have just to
expressed. So I was wondering if you would like to comment on the difficulty of defining it and whether or not we should stop using the term fiber and start to be much more discriminatory about the components of fiber and what we think their specific effects might be. That would be better for our development of products and also our practice.

Dr. Benninga: If, as you, the experts in the field find it very difficult to give a clear answer to this question at this time, I do have not a better suggestion.

Dr. Aggett: I didn’t want you to worry about the definition. What I am implying is that perhaps we should forget about the definition; perhaps we should start thinking about the various independent components of this thing we call fiber, the same way we are starting to mature our thoughts about fat. Now fat is totally meaningless to me in many ways, and similarly I think fiber is as well, because as you said one would be far more concerned about resistant starch or \( \alpha \)-amylase-resistant starch. In that case is it a native resistant starch or is it a natural state starch that has been cooled and has gone into a glass state and is therefore \( \alpha \)-amylase-resistant? Are we talking about some of the sources of gums, all of which have different effects, and really I think understanding these effects and how they are arising is going to take us forward far more effectively than just being concerned about fiber. I don’t think it helps us characterize the benefits and the problems.

Dr. Benninga: I am not aware at this moment if there is a diagnosis test or a laboratory procedure which gives you insights into which fiber you deal with. I am not aware of this, I don’t know if the audience has some suggestions about this.

Dr. Taminiau: But if you wish to separate it, then the goal might be to say I want this fiber separate because there is evidence, or we as pediatricians should study it in a certain context. Is that what you mean?

Dr. Aggett: Yes, we already have one simple demarcation between soluble and insoluble fibers, and we envisage that insoluble fibers work by water retention perhaps. Let’s face it, there is some degradation and fermentation in the colon on some of the insoluble fibers, and then one comes to the soluble fibers which might have different effects. Of course it is in the soluble fibers that many people are looking for due product development, and one of the big discussions recently has been in the area of probiotics. Whether or not one could actually accept, not fiber but inulin for example, as a fiber, that was the first grade discussion. The decision is whether or not one would like to accept inulin as a non-digestible carbohydrate fructo-oligosaccharide in the diet for a specific effect, and it is this functionality that I am really asking about, I am not really looking for a description of the state of the art. There is strategy for organizing our current knowledge to take it forward so we can then think in terms of the intraluminal fate of these various components and then in turn their impact on gastrointestinal and systemic function.

Dr. H. Hoekstra: Perhaps I can help a little bit in the discussion. We have defined fermentable and non-fermentable fibers. In a previous discussion we talked about the water-holding properties of the feces [1]. It seems that water-holding properties in non-diarrheal stools are very constant, and normal and hard stools may not differ so much in this respect. If the non-fermentable fibers are responsible for the water-holding properties the net difference in the situation of constipation might be the aspects of the fermentable fibers. So if there is good fermentation that leads to good colonic function, we can explain the studies you presented. In a situation with adequate amounts of non-fermentable fibers more of these sorts of fibers will not be beneficial, but more fermentable fibers such as glucomannan could be helpful. So I would suggest having studies addressing both components, the fermentable and the non-fermentable, in constipation.

Dr. Benninga: I agree with this opinion. However, if you look at the diet of children then all kinds of fibers will be included. It will therefore be very difficult to strictly
separate the soluble and the insoluble, or the fermented or the non-fermented fibers, and truly know which effect of fibers is beneficial in children with constipation.

Dr. Hernell: Isn’t that one of the problems, because most of the studies that you showed discussed only dietary fibers. With respect to functional outcomes you don’t really know exactly what people have been comparing because, as Dr. Aggett says, dietary fiber is not well defined. I think we need to agree on some kind of definition. If we want to compare functional outcomes we must really know what type of fiber we are comparing.

Dr. Benninga: I agree. But the same is true if you look at the studies in adults with a lower risk of developing colonic carcinoma. It is not known if this is caused by the effect of fibers or that other supplements are important in decreasing the risk of colorectal cancer.

Dr. Leathwood: Once you have defined fiber to your own satisfaction and identified the effects, the next problem is to communicate this information to consumers. We must not forget that many consumers attribute all sorts of benefits (?) to fiber, and these do not necessarily bear much relation to expert opinions about the benefits of fiber.

Dr. Benninga: Yes, but it gives rise to the same discussion. As we really don’t know how to define fibers and how to divide them, it makes it difficult to explain.

Dr. Hernell: When you give a recommendation as you did, age plus 5 g, one may wonder if the same type of fibers is applicable to all ages, or if different types of dietary fibers should be recommended for different age groups?

Dr. Benninga: I haven’t really thought about it. If you look at children’s diets, 75% of the fiber intake is non-soluble whereas only 25% is soluble, so perhaps we have to make this recommendation.

Dr. Hernell: I was thinking about breast milk. 20 or 15 years ago, we used to say that infants should not have too much fiber in their diets because they were not used to it, there is no dietary fiber in breast milk. Then we changed the definition of dietary fiber to non-digestible carbohydrates and all of a sudden there are a substantial amount of dietary fiber (oligosaccharides) in breast milk. So I mean it is perhaps time to question what type of dietary fiber should be recommended for what age group? May be we shouldn’t recommend dietary fiber, we should recommend how much fruits and vegetables children in various age groups should eat.

Dr. Taminiau: Is there any concern about micronutrients, with regard to age or risk?

Dr. Aggett: I don’t think there is. As Dr. Benninga pointed out, the opinion is that if one eats fiber at a reasonable level then there will not be a negative impact on nutrition in general and particularly on the minerals. Now clearly some of the issues arising from mineral availability relates to perceptions that there may be ionic binding between cations and fibers that would limit their availability. But interestingly I don’t think there are really any good studies over an extended period to substantiate if there is a negative impact of so-called high-fiber intakes. This has mainly been done in vegetarians, there is clearly a lot of adaptive capacity to acquire the calcium, magnesium, iron and zinc that is necessary. Perhaps when there is so much non-digestible carbohydrate that it displaces other items from the diet then there may be a negative impact, but that would apply to all nutrients and not just minerals.

Dr. Schmitz: Is it a question of definition to explain the contrast between two of the results you presented, the first one being the nice slide in which the increase in the amount of ingested fiber increased stool weight, and the following slide in which you showed that in the pediatric age there is nearly no difference between the ingestion of fibers in constipated and non-constipated children? Otherwise this contrast is difficult to understand.
Dr. Benninga: Adding more fibers to the diet is the first-line treatment in adults with constipation. More importantly it works in these patients. However in children with constipation, we don’t find beneficial effects of fibers on defecation frequency and stool consistency. Children don’t often take the fiber supplements because of the nasty taste. A solution might be the use of glucomannan.

Dr. Taminiau: You presented 14 g in Brazil, 11 g in Greece, and Holland 7 g. Is there a difference in fiber intake in the world?

Dr. Benninga: Although there are not many papers describing the amount of fiber ingestion, I think that there will not be a large difference between the Western world and South America. Even in higher socioeconomic class families, the same intake of fiber was found.

Dr. Taminiau: So is there any epidemiology in fiber content in the world you didn’t mention?

Dr. Benninga: There are not very many papers talking about fiber ingestion. But if you estimate there is not a big difference between the Western world and South America; in all countries there is a decreased intake of fibers, even when looking at higher socioeconomic class families, and it didn’t make any difference when they looked at fiber intake. So I think Holland is not very different from the rest of the world.

Dr. M. Hoekstra: I would like to confront you with one of your statements with respect to the effect of fibers on constipation. You said that there is a need for larger studies, but in my opinion a large study is not always better than a small study. So I would like to ask you whether the negative studies were underpowered? My second question is: if you try to make a conclusion from several studies, you almost always end up with inconsistencies. The solution to that is that the studies are compared with respect to the patients, whether they are the patients that are being treated as well, or looking at the methodology. Are the pro studies better than the con studies?

Dr. Benninga: You pointed out the difficulties in studying constipation. I think that you have to ask Dr. Staiano if she thinks that her study was underpowered. Of course you are correct that we don’t always need higher power studies, but in the majority of studies we did we always needed to have only a small beneficial effect, at least 150 patients, so I think 20 is perhaps not enough, but we will hear it from Dr. Staiano in a few moments. Another very difficult point in studying children with constipation is that there is not one definition for constipation. As I showed you in the Brazilian and Greek studies, I really think that the definition of constipation was not good. Therefore I think it is important that in a few weeks new criteria will be made and if we all stick to these criteria we might get the same population and more insight into the pathophysiology and how to treat these patients. I think that is the main weakness of our studies.

Dr. Kleinman: Do you think that there is some value in separating prevention from treatment when talking about constipation, given that for the most part when we treat constipation now most recommend increased dietary fibers? The compliance is so poor, however, that most of us now turn to a synthetic polyethylene glycol mixture that can be used very effectively often without additional stimulant laxatives. In discussing this, clearly if you are talking about a population-based approached, changing the diet makes a lot of sense, and yet if you are talking about treatment so many other things impact on successful resolution of constipation, particularly when it has been in place for months or years, that increased dietary fiber alone is likely to have less benefit there.

Dr. Benninga: I think it is a good point to talk about prevention in these children. Future studies will hopefully answer your question if early adjustments of prebiotics, such as FOS and GOS, will cause less constipation.
To continue this point: is it possible to identify risk groups that are prone to constipation? When prophylactic measures are needed, I think it is wiser to concentrate on these risk groups and not on the whole population.

That is a very good question too. It will be difficult however to identify risk groups. We know now that 30% of the children with constipation have a first- or second-degree relative who has constipation too. It might be useful to follow the children of parents who had childhood constipation themselves.

Can I come back to this prevention issue? Most of you from the Netherlands are aware that a nutritional analysis of Dutch children was done. From that, as I remember it, it was clear that the consumption of fiber-containing foods by children in the Netherlands is tremendously low. So if you could change the dietary habits, as you showed last week during the pediatric conference in the Netherlands, by letting them eat full-fiber pasta, if you get children to eat that kind of pasta and brown bread and fruits and vegetables, I think 50% of the problem would be solved, and you don't need to identify risk groups and give them additional fibers whatsoever. But that should be our first concern in my opinion.

I think this is wishful thinking. As I stated before, in 1995 a conference was held in the US on adding fibers to supplements for children in the US. Disappointingly the outcome of this conference was that the fiber and vitamin intake didn't change despite an enormous advertising campaign and information to the public.

You are probably right. Tomorrow morning we are going to talk about junk food, so I won't say anything more but I will come back to it tomorrow.

Not looking at your slide, it must not be too difficult for industry to make a fiber-enriched product that tastes good to children.

You mean that it won't be difficult because there are of course already fiber-enriched supplements, but are you talking about healthy or are you talking about constipated patients?

We can talk about all categories, but if you talk about constipated patients then it must be possible. I mean children don't always like fruits, they want other things that taste better in their opinion, and it has to be possible to make something that tastes sweet and contains fibers. Why can't we make that? It is not that difficult.

I will ask the people from Nestlé.

We are following the recommendation of age plus 5 for the toddlers after 1 year of age, but between 6 months and 1 year it is more difficult to make a precise recommendation. I was just doing the calculation in our infant cereal. For stage 1 globally we have two portions, so between 4–6 and 6–8 months, we have about 2.5 g fiber from infant cereal. So if some fruits in jars are added in which there are also fibers and vegetables, particularly carrots, the intake of fibers could be fulfilled. But we don't know if age plus 5 must also be followed between 6 and 12 months.

Was it is not difficult to make the product?

No, it is not difficult to make the product, but a difference must be made between cellulose and other dietary fibers because it is probably less palatable when cellulose is increased.

But I think you have to make something like a candy bar, something that taste like Bounty or Mars and contains fibers. You really have to adjust it to the tastes of the children.

Let's wait until tomorrow with that discussion.

It seems to me that we are going to medicalize our children too much, because if we are going to make a candy bar with vegetables I know many more tastier foods that can be useful in this respect. In your slides I did not see the length of the observation in the treatment of constipation with vegetables and fruits, nor the age of
the subjects. So I would like to know your opinion on the minimal time of using normal and tasty food before going on to using a laxative, because children comply differently to adults. In my opinion miracles do not appear all the time, so we probably need time to get good results using correct food.

**Dr. Benninga:** I can’t answer, I don’t know what the best time to start with laxatives is. As you know lactulose is also a non-digestible carbohydrate and we start it immediately if we think that the child needs it, and that can be already after 10 days or even earlier. I never wait in starting laxative if the child really has problems. It is also very difficult to define what constipation is because I think that is what you mean, how long can you wait until the defecation problems resolve, and I can’t answer this question. If the child has pain during defecation, if he cries around the defecation and the defecation frequency is less than 3 times/week, then I think you have a good reason to start laxatives. We know now from studies by Dr. Staiano and our group that if you start treating these constipated infants early, then they tend to do better in life than children who started treatment later.

**Dr. Taminiau:** Dr. Staiano can you comment and then can you comment on what Dr. Benninga published on glucomannan. There is a limit of 5, why didn’t you give more? Perhaps Dr. Kneepkens can also comment because he worked with glucomannan in the stomach to delay emptying.

**Dr. Staiano:** I want to say that we should make a difference between the efficacy of fibers in normal subjects and in constipated children. In adults, fibers have a very good efficacy on stool habit, even in constipated adults because one of the effects of the fibers is to increase stool size which determines the distention of the lumen and this evokes peristalsis. We know that in most constipated adults the problem is delayed transit in the proximal colonic segments. In contrast, in children constipation is mainly due to delayed transit in the rectum [1]. The effect of fibers in rectal constipation is different than in patients with a delay in the more proximal segments of the colon. In fact, it has been reported that an increased amount of fibers in adults with rectal dyschezia, i.e. a rectal delay in the transit time just at the level of the rectum, may worsen the constipation due to the difficulty in the elimination of stools with an increased size. So far, in children with functional constipation, if we increase the amount of fibers too much we could create a further problem in the elimination of this larger stool. In the past, we evaluated the efficacy of glucomannan, a soluble fiber, as a treatment for chronic constipation in children with severe brain damage [2]. The study demonstrated that glucomannan has a beneficial effect only on bowel habits but not on gastrointestinal transit time. The increased bowel frequency despite the prolonged transit time, could be explained by the frequent passage of small amounts of less consistent feces, without improvement in the progression of the intestinal contents. So, in these patients, severe damage to central structures could be responsible for the dis-regulation of normal content progression through the large bowel. Differently, in the last study done by Loening-Baucke et al. [3], the effect of glucomannan and placebo was evaluated in 31 children with chronic functional constipation with and without encopresis, recruited from the Pediatric Clinics of the University of Iowa and the University of Naples. We used glucomannan at a dose of 100mg/kg body weight daily, maximal 5g/day, just to be sure not to give too much fiber so as to have an opposite effect. Also in these children we found fiber to be beneficial in the treatment of constipation with and without encopresis, with an improvement in bowel habits. Symptomatic children already on laxatives still benefit from the addition of fibers. In conclusion an adequate amount of fiber in the diet is certainly very important for the treatment of constipated children, however I believe that we have to be careful in advising large amounts of fibers because in children there is a delay in the rectum and sometimes fibers could worsen the condition.
Fibers in Childhood

Dr. Kneepkens: I don’t have much to add to that, but we have to realize that glucomannan is not very much different from galactomannan, present in carob gum, that we use in the treatment of regurgitation in infants, and we know that it also influences the stools of the children. Both galactomannan and glucomannan are fermented completely in the proximal colon, but at a rate which is a lot lower than, for instance, lactulose. It may act as something in between lactulose and non-fermentable fiber and have an influence especially on bacterial growth, bacterial mass, and fecal mass. So there may be a possibility for galactomannan and glucomannan to be used in constipation, but I don’t think they are better than what we use at the moment, microgal, which also increases fecal weight.

Dr. Benninga: I totally agree.

Dr. Taminiau: I would like to reemphasize what Dr. Benninga showed about the digestible fibers and that digestion is not solid and water absorption but also the energy absorption. Adults can absorb about 80–100 g, it is 400 kcal in the colon and also medium-chain triglycerides, if they arrive in the colon, they are digested and about 100 g of medium-chain triglycerides can be put into short chains and absorbed, so there is about 400–800 cal. Then there are the beautiful studies by Diamond on maximal absorption in animals. He used a python as a model and let him eat a sheep to study the upregulation of absorption, what the maximum is. He showed that our nutrient-absorbed carriers such as the glucose sodium carrier are not upregulated in the human because we probably have so much reserve capacity in the colon, also in the newborn and the premature, up to 800 cal. So it is really the digestive organ that is very important because we don’t upregulate in the small bowel. I would like to thank you all for participating. I would like to thank Dr. Staiano for talking about motility, Dr. Bueno for going from motility to transport and pathophysiology, Dr. Benninga for addressing fiber with all its problems, and Dr. Aggett for defining the problems we have with the definition.

References