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REVIEW

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Use of fiber-containing enteral formula in pediatric clinical practice: an expert opinion review

Paolo Lionetti [a], Eytan Wine [b], Rinat Ran Ressler [c], Gerard J. Minor [d], Giles Major [e], Boutaina Zemrani [f], Frédéric Gottrand [g] and Claudio Romano [h]

[a]Department Neurofarba, University of Florence - Gastroenterology and Nutrition Unit, Meyer Children's Hospital, Firenze, Italy; [b]Division of Pediatric Gastroenterology and Nutrition, Department of Pediatrics, University of Alberta, Edmonton, Canada; [c]Nestle Product Technology Center, Nestlé Health Sciences, Bridgewater, NJ, US; [d]Pediatric Gastroenterology Hepatology and Nutrition, Kidz Medical Services, Florida, USA; [e]Department Gastrointestinal Health, Nestlé Institute of Health Sciences, Lausanne, Switzerland; [f]Clinical Research and Development, Pediatric Medical Nutrition, Nestlé Health Science, Lausanne, Switzerland; [g]Division of Pediatric Gastroenterology, Hepatology and Nutrition, Institute for Translational Research in Inflammation, University Lille, Lille, France; [h]Pediatric Gastroenterology and Cystic Fibrosis Unit, University of Messina, Italy

ABSTRACT

Introduction: Children who require enteral nutrition often report gastrointestinal symptoms. There is a growing interest in nutrition formulas that meet nutritional requirements and also maintain gut ecology and function. Fiber-containing enteral formulas can improve bowel function, promote the growth of healthy gut microbiota, and improve immune homeostasis. Nonetheless, guidance in clinical practice is lacking.

Areas covered: This expert opinion article summarizes the available literature and collects the opinion of eight experts on the importance and use of fiber-containing enteral formulas in pediatrics. The present review was supported by a bibliographical literature search on Medline via PubMed to collect the most relevant articles.

Expert opinion: The current evidence supports using fibers in enteral formulas as first-line nutrition therapy. Dietary fibers should be considered for all patients receiving enteral nutrition and can be slowly introduced from six months of age. Fiber properties that define the functional/physiological properties of the fiber must be considered. Clinicians should balance the dose of fiber with tolerability and feasibility. Introducing fiber-containing enteral formulas should be considered when initiating tube feeding. Dietary fiber should be introduced gradually, especially in fiber-naïve children, with an individualized symptom-based approach. Patients should continue with the fiber-containing enteral formulas they tolerate best.

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Dietary fiber; enteral nutrition; fiber; formula; pediatrics

1. Introduction

Dietary fiber is an essential component of the human diet and a major determinant of digestive health [1]. Beyond the bulking capacity of fiber which facilitates bowel movements, fermentation of dietary fiber by the gut microbiota produces a wide range of compounds, such as short-chain fatty acids (SCFA), which can have benefits beyond the gastrointestinal (GI) system, including metabolic and immune functions [2–7]. Thus, dietary fiber has gained much attention over the past few decades as an important component of nutritional support, including enteral nutrition (EN). Fiber is generally considered to be highly beneficial, but there are some specific settings where it may be detrimental, so its use in any individual requires judgment.

EN is a commonly utilized method of nutrition support in infants and children who cannot meet their nutritional requirements orally. It is used in in-patient and outpatient settings in various disease states. In pediatric patients, it is important to ensure that EN meets dietary requirements for growth and development with a tolerable safety profile [8]. Nonetheless, adverse events are common with EN, including diarrhea and constipation, which can cause distress, intolerance, undernutrition, and fluid/electrolyte imbalance [9–11]. Therefore, fiber-containing formulas have been investigated for their potential positive effects on gut microbiota and intestinal function. There is growing evidence of the nutritional benefits of fiber-containing formulas and their tolerance in children receiving EN [12].

While the health benefits of dietary fiber are well established, concerns remain regarding the tolerance of pediatric patients when adding fiber to EN formulas [13,14]. Long-term use of fiber-containing enteral formulas has not yet been well-studied in the literature, and the role of fiber in improving GI symptoms in tube-fed patients is not well-characterized [10]. The result is a lack of guidance on the appropriate use of fiber-containing enteral formulas in pediatrics, with variability

CONTACT Paolo Lionetti paolo.lionetti@unifi.it Department Neurofarba, University of Florence - Gastroenterology and Nutrition Unit, Meyer Children's Hospital, Firenze, Italy

Article highlights

- Dietary fiber plays an important role in pediatric nutrition by supporting gut health and microbiome and promoting normal laxation. Nonetheless, practical guidance on the use of fiber containing EN in the pediatric population is still lacking.
- Current evidence supports the use of dietary fiber in enteral feeding formulas as a first line nutritional therapy.
- Fiber should be considered for all patients requiring enteral nutrition and can be gradually introduced from 6 months of age.
- The use of a mixture of bulking and fermentable fiber is suggested as a preferable approach, particularly for longterm feeding.
- There is no universal consensus on the dose of fiber to use in tubefed children with acute and chronic illness. However, based on clinical experience an estimated 10 g/day <3 years and >20 g/day for ≥14 year old adolescents might be considered.
- Dietary fiber should be introduced gradually, especially in fibernaïve children, with an individualized symptombased approach.
- Patients should continue on the fiber containing formula they tolerate best, with fiber intake adapted to their tolerance. Longterm fiber intake might be recommended to prevent the recurrence of gastrointestinal (GI) problems.

between international guidelines [10,15,16]. Thus, this article aims to collect the opinions of experts on the importance of dietary fiber in pediatric EN based on available literature and clinical and research experience. The experts share their insights and opinions on the target patients for fiber-containing enteral formulas, types, and amounts of fiber to be considered for pediatric EN, and the appropriate nutritional approaches in EN therapy.

2. Review development

Eight experts attended an expert meeting ahead of the 54th Annual Meeting of the European Society for Pediatric Gastroenterology, Hepatology, and Nutrition (ESPGHAN) in Copenhagen to discuss the benefits and clinical applications of fiber-containing formulas in pediatric EN. Comments and feedback were collected from the experts to develop the present expert review and were supported by a bibliographical literature search on Medline via PubMed to collect the most relevant articles. The keywords used in the literature search were: (fiber-fortified OR fiber-fortified OR fibrous) AND (enteral nutrition OR tube feeding) AND (pediatric OR children). The manual screening of relevant references complemented the online bibliographic search.

3. Benefits of dietary fiber and dietary recommendations for children

The definition of 'fiber' varies across countries and international organizations, and it has been challenging to get a consensus on a single definition due to differences in biological, chemical, and physiological characteristics. The Institute of Medicine (IOM) defines 'dietary fiber' as 'nondigestible carbohydrates and lignin that are intrinsic and intact in plants.' At the same time, 'functional fiber' consists of 'isolated, nondigestible carbohydrates that have beneficial physiological effects in humans,' with total fiber being the sum of nonfunctional fiber and functional fiber [17]. Such definition encompasses natural and synthetic fibers, generally demonstrating positive human physiological benefits. In 2009, the codex Alimentarius commission defined dietary fiber as 'carbohydrate polymers with three or more monomeric units, which are neither digested nor absorbed in the small intestine.' This includes edible carbohydrate polymers naturally occurring in the food, carbohydrate polymers obtained from food raw material by physical, enzymatic, or chemical means, and synthetic carbohydrate polymers which have been shown to have a physiological effect of benefit to health [18]. The European Food Safety Authority (EFSA) defines the dietary fiber as 'nondigestible carbohydrates plus lignin' [19].

Figure 1 shows the potential physiological benefits of dietary fiber in humans. Increasing fecal bulk and promoting defecation frequency are two of the main advantages of insoluble fibers [20]. Some fermentable fibers work as prebiotics, boosting populations of 'beneficial bacteria like bifidobacteria and lactobacilli in the colon [21]. Dietary fibers have been shown to influence insulin secretion and satiety via their effects on a broad range of gut hormones known as incretins [22]. Certain fibers can bind bile acids and prevent their development into micelles, increasing the excretion of bile acids and cholesterol in the stool [23]. Improved cognition in prepubertal children, weight control, and prevention of constipation were also reported as potential long-term health benefits of dietary fiber [6,24]. Patients with constipation can benefit from fiber supplements, high-fiber cereals, and wheat bran that help normalize bowel function [25].

The density, variety, structure and metabolic activity of the gut microbiota are all significantly affected by the consumed diet. Microbiota composition is linked to long-term dietary habits, particularly the consumption of protein, animal fat, carbohydrates, or plant-based meals [26]. High fiber intake and low refined food consumption may enhance microbiota diversity. As seen in the Western world, reduced fiber intake over the long term may lead to the irreversible elimination of essential microbial species, as shown in rodents [27]. In humans, dietary habit modifications in the course of urbanization play a role in shaping gut microbiota, and fiber-degrading bacteria are at risk of being eliminated by the fast-paced globalization of foods and by the advent of a westernized lifestyle [28–30]. Gut microbiota populations adapt within 24 hours to substantial alterations in macronutrient intake, although more sustained changes in diet are needed to sustain changes in composition [31].

Lack of carbohydrates over time significantly decreased the amount of fiber-degrading bacteria, while the quantity of *Streptococcus*, *Eggerrthella*, and *Lactococcus* rose, resulting in reduced levels of SCFAs [32]. SCFAs are of crucial physiological importance within the gut providing energy requirements for enterocytes and regulating intestinal permeability and peristalsis [33]. In addition, SCFAs reaching the circulation exerts favorable systemic effects on the immune system, including boosting T cell development and associated immunity and immunological tolerance [34,35] and having potential advantages in preventing or reducing autoimmune diseases, including allergic disease, inflammatory gastrointestinal disorders, inflammatory arthritis, and diabetes [36,37].

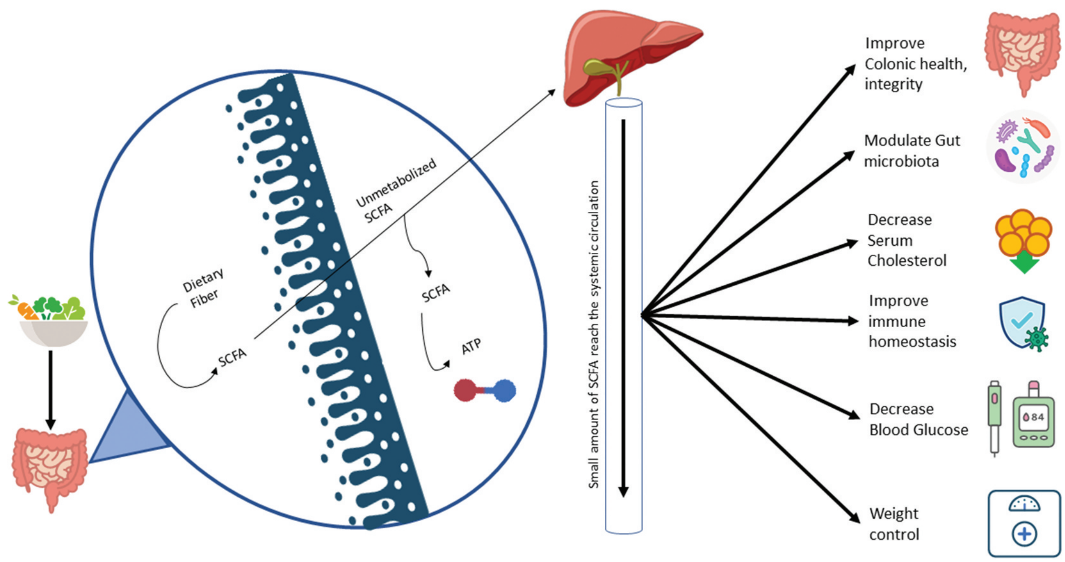

Figure 1. The potential physiological benefits of dietary fiber in humans. SCFA, Short-chain fatty acid.

For example, fiber supplements or high-fiber foods are suggested for many gut disorders, including in adult hemorrhoids, constipation, diverticular disease, irritable bowel syndrome (IBS), inflammatory bowel disease (IBD), duodenal ulcers, and gastroesophageal reflux disease (GERD) [38,39]. Patients with constipation or hemorrhoids can benefit from fiber supplements, high-fiber cereals, wheat bran, and increased dietary fiber intake. Hemorrhoid treatment and prevention may be aided by a diet higher in fiber [40]. Consuming high amounts of dietary fiber has been linked to preventative, ameliorative, and protective effects against the recurrence of diverticular disease [41,42]. For IBD, ulcerative colitis and Crohn's disease (CD), fiber diet was associated with reduced risk of IBD of CD [43], improved quality of life, reduced Serum amyloid A, and reduced serum level of C-reactive protein in UC patients [44]. Previous reports suggested that dietary fiber in meals or supplements, together with the sympathetic support of a primary care practitioner, may effectively relieve symptoms of IBS [45]. Although the evidence is scant, GERD and duodenal ulcer disease may be prevented by consuming guar gum and other soluble fibers [46]. A previous report demonstrated that a fiber-enriched diet led to a significant decrease in heartburn frequency per week, a decrease in the number of GERs, and an increase in minimal lower esophageal sphincter resting pressure [47].

In children fiber-containing EN formulas are not routinely used for patients who need nutritional support and have a normal gut function. In contrast, they are frequently reserved for managing some specific GI conditions, including functional disorders (FGIDs); however, there is a lack of large, controlled trials. Studies showed that fibers benefit children with FGIDs with no distinction between fermentable and/or bulking fiber [1]. In functional constipation, the ESPGHAN and North American Society for Pediatric Gastroenterology, Hepatology and Nutrition (NASPGHAN) recommend a normal fiber intake with no indication of the type of fiber that might benefit these children [48]. A systematic review of 10 studies, including 728 children, and one follow-up study, including 80 children, compared the effect of seven different mixtures of fibers, prebiotics, and/or infant formulas with placebo or control treatment. The results showed evidence that specific fibers or prebiotic supplements may be more effective than placebo or as effective as a laxative treatment [49]. In pediatric short bowel syndrome (SBS) and in critical clinical conditions, such as oncological patients who need chemotherapy, adding fiber to enteral feedings is a treatment method to manage increased stool output. However, there are no standardized recommendations on using fiber in these settings, including type, dosage, titration strategies, etc [50].

In children with a normal gut function who require nutritional support both orally or by tube feeding, benefits of fibers in enteral formulas have been shown in clinical studies, including decreased diarrhea, lower stool pH, improved bowel frequency and improved fecal microbiota profile [1].

Beyond the digestive systems, a meta-analysis found that an increase in the dietary fiber of 7 g per day was associated with a significant reduction in the risk of diabetes (6% risk reduction; $p = 0.001$), rectal cancer (9% risk reduction; $p = 0.007$), colorectal cancer (8% risk reduction; $p = 0.02$), ischemic and hemorrhagic stroke (7% risk reduction; $p = 0.002$), and cardiovascular disease (9% risk reduction; $p < 0.001$) [51]. Daily fiber consumption between 25 g and 29 g was linked with a 15% risk reduction in all-cause mortality, according to a 2019 meta-analysis [52].

Recommendations for daily fiber intake for healthy children vary across international societies. They have been expressed in various ways, either as a function of energy intake (g/1000 Kcal), in grams per day, or in grams per kilogram of body weight. Most of these intake recommendations are based on scientific evidence of the relationship between dietary fiber intake and adult health outcomes. Williams et al. (1995) suggested that children older than two years should consume at least the amount of fiber equivalent to their age plus 5 g/day, up to a maximum of 10 g/day [53]. The Institute of Medicine

Table 1. Dietary fiber recommendations for children.

EFSA [19]		UK SACN [51]		USA IOM [17]		Australian NHRMC [55]		
Age	Reference value	Age	Reference value	Age	Reference value	Age	Reference value	Williams et al. [53]
1–3	10 g/day	2–5	15 g/day	1–3	19 g/day	1–3	14 g/day	Age plus 5 g/day for those over two years (minimum) up to 10 g/day (maximum)
4–6	14 g/day	5–11	20 g/day	4–8	25 g/day	4–8	18 g/day	
7–10	16 g/day	11–16	25 g/day	9–13	Girls: 26 g/day Boys: 31 g/day	9–13	Girls: 20 g/day Boys: 24 g/day	
11–14	19 g/day	16–18	30 g/day	14–18	Girls: 26 g/day Boys: 38 g/day	14–18	Girls: 22 g/day Boys: 28 g/day	
15–17	21 g/day							

EFSA: European Food Safety Authority; SACN: Scientific Advisory Committee on Nutrition; NHRMC: National Health and Medical Research Council.

(IOM) has advocated that healthy adults receive 14 g of fiber for every 1,000 calories they consume [17]. Extrapolating this recommendation to children would mean that children aged 1–3 years should receive an intake of fiber of 19 g/day, while children aged 4–8 years should receive 25 g/day [54]. The EFSA has set lower recommended daily fiber intake for children, ranging between 8.4 to 10.4 g of fiber per 1000 kcal (2 to 2.5 g per MJ) [19]. In Australia, fiber intake has been derived from National Dietary Surveys for different age groups [55]. Table 1 summarizes the dietary fiber reference values established by the main international societies. However, it is worth noting that the current guidelines for daily fiber intake refer to total fiber regardless of the source or fiber quality provided. This is critical since consuming fiber from various types and sources results in various functional and physiological impacts on the human body, as not all fibers are the same [56].

4. Fiber-contained enteral formulas and different types of fiber used in enteral products

4.1. Physiochemical properties of different types of dietary fiber used in enteral products

The chemical and physical properties of fibers can vary depending on their origin (Table 2).

Historically, fiber was classified into a soluble and insoluble fiber. Although solubility was previously used to categorize dietary fiber, viscosity and fermentability may be more important concerning specific physiological effects, and so nutrition and health [57]. Fibers that are fermentable by colonic bacteria can be broken down into energy, while fibers with gel-forming properties are known as viscous fibers. Fiber fermentability depends on how much it can be metabolized by gut microbiota. This is determined by the physical and chemical characteristics of fiber that affect bacteria accessibility. Compared to insoluble fiber, soluble fiber is often more fermented and has a higher viscosity. Bulking fibers are predominantly insoluble and poorly fermentable, while certain soluble fibers (such as partially hydrolyzed guar gum [PHGG] and acacia gum) are not viscous [58]. However, there are some exceptions to this; for example, insoluble soy polysaccharides may be well fermented, and soluble fibers such as oat bran and psyllium can increase stool mass [59]. Of note, nutrition labeling still distinguishes between insoluble fiber and soluble fiber.

More recently, it has been suggested that binding, structural, and transport barriers are more important classifiers of fiber and should be used to discriminate between different fiber types due to their direct association with dietary fiber outcomes [41]. In this classification, it is suggested that fiber mass structure may play a role in determining the rate of food digestion and absorption. In addition, the molecular binding of fiber with other micronutrients, enzymes, or bacteria can affect fiber digestion, passage, and fermentation. At the same time, transport barriers can restrict molecular transport. In turn, the authors proposed these three physicochemical properties – binding, structuring, and transport barriers – as the most important determinants of dietary fiber functionality [60].

Several types of dietary fiber are used in enteral products. Soy polysaccharides are a fiber source obtained from soy cotyledon and consist of several fiber components, including cellulose, hemicelluloses, lignin, and pectin-like molecules. PHGG is a nonviscous soluble fiber that is obtained from guar gum through partial enzymatic hydrolysis. Although the viscosity of PHGG is minimal compared to its source, it appears to retain the lowering effect on glucose and insulin levels in healthy and diabetic subjects [61,62]. Inulin-type fructans, which include fructooligosaccharides (FOS), oligofructose (OF), and inulin, are frequently included in enteral formulas with GI and immunological benefits but have also been linked to pro-inflammatory effects in pediatric inflammatory bowel diseases [63]. Acacia gum (AG) is a soluble fiber that has gained popularity due to its prebiotic properties and high tolerance levels. Human studies have demonstrated that 3 g

Table 2. Physicochemical Characteristics of different types of fibers used in EN products.

Classification	Solubility	Fermentability	Viscosity
PHGG	Soluble	Fermentable	Non-viscous
Soy polysaccharide	Insoluble	Fermentable	Non-viscous
Inulin-type fructans	Soluble	Fermentable	Non-viscous
Acacia gum	Soluble	Fermentable	Non-viscous
Cellulose	Insoluble	Nonfermentable	Non-viscous
Resistant starch	Insoluble	Fermentable	Non-viscous
Pectin	Soluble	Fermentable	Viscous

PHGG: partially hydrolyzed guar gum.

of AG per day is sufficient to promote the development of bifidobacteria when paired with the same amount of FOS [64].

Starch and starch breakdown products, which are not absorbed in healthy people's small bowel and move to the colon, are called resistant starch (RS) [65]. During fermentation, RS produces more butyrate and less acetate than most other fibers, enhancing the proliferation of bifidobacteria [66]. Cellulose is another insoluble fiber composed of glucose polymers and effectively produces bulk stool and suppresses osmotic diarrhea [67]. Field pea hulls are the source of insoluble outer pea fiber, which comprises hemicellulose, cellulose, and pectic materials. Pea fiber is mainly used to increase the amount of fiber in products without changing their functional or technical features, and it makes healthy adults have heavier stools [68].

4.2. Commercially available fiber-containing formulas

Table 3 shows several commercially available fiber-containing formulas with different types and sources of fiber. Several technical points should be considered when adding fiber into formulas:

- Viscosity: Fiber may add viscosity to the formula, which can affect the formula's flowability. These considerations are especially important in the pediatric population whose feeding tube size is small.
- Dose: The nutritional composition of formulas aims to address the needs of children of different ages. Often, the different nutritional needs of children at different ages are addressed by providing different volumes of the same formula. This practice may affect the amount of fibers added to the formula to limit tolerance issues in higher volume consumption.
- Personalization: Some healthcare providers may prefer to choose the type and amount of fiber according to each child's specific needs. It is possible to add fiber as needed, but mixing an external source of fiber into a formula may cause clumps or affect the formula's characteristics, such as viscosity.

4.3. Use of fiber blends in pediatric EN

Current enteral formulas include different types and doses of fiber in polymeric and semi-elemental formulas, which makes

Table 3. Examples of fibers in commercially available fiber-containing formulas.

Added Fiber	Type of Fiber	Type of Products*	Energy Density (kcal/ml)	Dose g/ Liter	Main Intended Use
PHGG	Soluble	• Semi-elemental, w/PHGG • Semi-elemental, high-energy • Semi-elemental, high-protein • Semi-elemental, w/Fiber • Polymeric, w/real food ingredients, high-energy • Semi-elemental, w/real food ingredients	1.2 1.5 1.2 1.0 1.5 1.5	12 6 4 4 12 12	TF
Agave Inulin	Soluble	• Semi-elemental, plant-based • Semi-elemental, plant-based, high-energy • Polymeric, plant-based	1.0 1.5 1.2	8 12 12	• TF • ONS
Mixture of Acaia Gum, FOS, Inulin	Soluble	• Polymeric, w/real food ingredients, reduced-calorie	0.6	10	TF
Mixture of Pea Fiber and PHGG	Mixture of non-soluble and soluble	• Semi-elemental, plant-based, w/ real food ingredients • Polymeric, plant-based, w/real food ingredients • Polymeric, high-energy	1.4 1.0 1.5	10 10 8.4	• TF • Dual use
Mixture of Inulin and FOS	Soluble	• Semi-elemental, high-energy • Semi-elemental, w/fiber	1.5 1.0	3 4	TF
Mixture of Pea, FOS, and Inulin	Mixture of non-soluble and soluble	• Polymeric	1.0	3	Dual use
Mixture of Soy Polysaccharides, Resistant Starch, Inulin, Arabic gum, Cellulose, Oligofructose	Mixture of non-soluble and soluble	• Polymeric • Polymeric, high-energy	1.0 1.5	8 8	Dual use
Mixture of Short Chain FOS and Soy Fiber	Mixture of soluble and non-soluble	• Polymeric	1.0	12.6	Dual use
Short Chain FOS	Soluble	• Polymeric, w/fiber • Polymeric, high-energy • Polymeric, reduced-energy • Semi-elemental • Semi-elemental, high-energy	1.0 1.5 0.75 1.0 1.5	12.6 12.6 12.6 3 4.6	Dual use
Fibers from Real Food	Mix	• Polymeric, w/real food	1.2	16.6	TF

TF – tube feeding; Dual use – Formula can be used as a sole source of nutrition or as Oral Nutritional Supplements (ONS); Semi-elemental – peptide-based formula. The table was generated based on information available on the companies' internet sites, accessed Oct 2022.
*Not exhaustive list.

comparing their effect difficult. Furthermore, the fiber content of some currently available enteral formulas may be too low compared to estimated fiber requirements resulting in low fiber intake [69]. While some formulas provide a mixture of fibers, others include soluble fiber. In a regular diet, most fiber-containing foods contain around one-third soluble and two-thirds insoluble fiber. In recent years, there has been a growing interest in using blenderized feeds and commercial real food-based formulas. These formulas include a mixture of food ingredients (such as peas, green beans, peaches, etc.), which provide a fiber blend that mimics a normal diet [70].

Despite the beneficial effects of fiber overall, fiber-containing formulas are not routinely used in clinical practice. According to a home enteral nutrition survey in 2005, only 7% of the commercially available enteral preparations used were fiber-supplemented in the pediatric population [71]. In another home enteral nutrition survey conducted in Poland in 2014, including 456 patients (142 children and 314 adults), fiber-rich diets were used in only 9% of cases [72]. A recent Polish nationwide home enteral nutrition survey performed on adults in 2018 found that about 17% of enteral formulas used were supplemented with fiber [55].

4.4. Side effects of dietary fiber for children receiving EN

Overall, fiber-containing formulas are generally well-tolerated; however, dietary fiber may be associated with some side effects in specific cases. High fiber intake can cause flatulence and abdominal distension, especially when introduced rapidly in subjects naïve or consuming low amounts of fiber [73]. Previous reports showed that higher fiber intake may lead to constipation, similar to what is observed with lower intake [74]. However, such findings may be attributed to the various underlying etiology of constipation rather than an actual impact of high fiber intake [75]. Certain types of fiber can have a pro-inflammatory role during active inflammation. In a recent report, β-fructan induced pro-inflammatory response in some patients with active inflammatory bowel disease, highlighting a potential detrimental effect of some fibers during inflammation [63].

5. Clinical evidence on the use of fiber-containing enteral formulas in children

The benefits of fiber-containing EN formulas on gut function have been the focus of several clinical studies. Some studies tested isolated fibers, such as PHGG, while others tested specific blends of fiber for a few weeks to six months. Clinical studies on fiber covered a range of pediatric disorders, including children with neurological impairment, cystic fibrosis, cardiac disease, liver transplant, bone marrow transplant, cancer, and growth failure. However, the sample size was generally small in most studies. Overall, the evidence supports the safety and tolerability of fiber across different age groups [59,69,76,77]. Although more evidence is available in adults, extrapolating findings from adult studies in children with developing gastrointestinal systems is difficult, as fiber may have different actions on the gut and health in children compared to adults.

In a randomized crossover trial, a fiber blend of FOS (3.5 g/day) and pea fiber (3.8 g/day) for two weeks improved stool consistency and reduced the proportion of hard and watery stool in children with compromised gut function [78]. Evans et al. studied the effects of an enteral formula including six fibers (soy polysaccharide, cellulose, AG, FOS, inulin, and RS; a total of 11.2 g/L) during six months in 25 tube-fed children with a range of medical conditions. They found evidence of reduced constipation, less need for laxatives, and decreased abdominal pain on the fiber-containing formula compared to the fiber-free formula [69]. A similar finding was reported in 45 children with chronic illness who received fiber supplementation in pediatric sip feeds at 20 g/L for 12 weeks [79]. Compared to fiber-free sip feeds, laxative usage decreased while GI tolerance, anthropometry, and nutritional biochemistry were comparable for both groups. A fiber blend of five fibers (oat, soy polysaccharide, acacia gum, carboxymethylcellulose, and FOS; 25% soluble) was investigated in a randomized controlled trial in tube-fed children for three weeks. Significant improvement in GI symptoms scores was found despite the non-significant changes in stool consistency [80]. Data on the use of fiber in critically ill children is lacking. A previous randomized trial on critically ill children showed that a synbiotic blend-containing enteral formula was well tolerated and increased the beneficial fecal bacterial groups [9].

Concerning the effect of dietary fiber on gut microbiota, a prospective study on 67 pediatric cancer patients showed that the 70:30 blend of FOS and inulin led to a significant increase in the fecal Lactobacilli level after one month of supplementation of 1.2 g/day [81]. Supplementation of the same formula at 2.5 g/day for three weeks significantly increased the fecal bifidobacterial levels, with a trend toward improved fecal Lactobacilli levels [82]. In a randomized crossover design, a six-fiber formula for three months increased fecal *Bifidobacterium* levels for 12 weeks compared to the fiber-free formula [77]. Notably, a prospective study over ten weeks found that the 70:30 blend (1.7 g/day) supplementation was associated with improved IgG antibody response and growth [83]. In an observational study by Kansu et al., high-fiber EN formulas significantly improved the anthropometric parameters, with a well-tolerable safety profile, in children with growth failure [12]. Finally, previous studies suggested that fiber may affect the bioavailability of some micronutrients, such as zinc [84]; however other studies do not support these findings [69,79].

Although the clinical benefits and tolerability of fiber-containing EN formulas are consistently supported in the literature, well-designed studies with larger sample sizes are still needed in specific patient populations of children receiving EN. In adults, higher intakes of dietary fiber have been linked to a reduced risk of chronic diseases such as cardiovascular disease, type 2 diabetes, obesity, and cancer [1]. The evidence is lacking to confirm these benefits in childhood; however, it seems reasonable to recommend fiber in children for their future adult health.

6. Conclusion

Although there is clinical evidence for the use of some fibers such as PHGG, FOS, and/or inulin, future research is warranted to tailor the fiber choice according to the patient's needs.

There is a need for primary research to guide the selection of different fibers and their effects, as the current recommendations rely on expert opinion. This can aid in the development of personalized diets, which can also be supported by the use of microbial profiles to guide diet composition. Future research should also assess the impact of introducing a high amount of fiber in constipated children.

7. Expert opinion (Box 1)

7.1. The targeted population for fiber-containing formulas

Recommendations on the use of fiber-containing formulas in specific patient populations are lacking. The 2010 ESPGHAN committee on nutrition states that a fiber-containing formula is appropriate for most pediatric patients requiring EN [85]. Clinical evidence supports the use of fiber in children receiving EN support in various clinical conditions [78,86]. Data show that fiber-containing EN formulas can modulate gut microbiota, improve GI tolerance, and decrease blood glucose levels in glucose-intolerant patients. Therefore, the expert panel recommends that dietary fiber should be included in the diet of all pediatric patients and that fiber-containing formula should be considered in all tube-fed children unless when contraindicated in specific situations or poorly tolerated. Children who receive EN can benefit from fiber-enriched whole food to improve GI function, anti-inflammatory effects, enhance glycemic profile, and increase satiety. Future studies in specific patient groups with a paucity of clinical data (such as cardiac and ICU patients) are needed to provide supportive data on the safety, tolerability, and benefits of fiber-containing formula and avoid unnecessary restrictions.

Previously, fiber-containing formulas were recommended for children over the age of two. However, it is now clear that enteral feeding should reflect the natural transition from breast milk to complementary foods as much as possible. During the first few months, a breastfed child will not have fiber, nor should a tube-fed child. From about six months of age, fiber can be introduced in most children.

Clinical conditions in which fiber may be contraindicated include bowel obstruction or stenosis, acute inflammation, and ileostomy. However, there are no specifically defined contraindications, and the introduction of fiber is set and assessed according to a follow-up of tolerance of patients.

7.2. Fiber selection in different clinical settings

Various fiber levels and sources are used in enteral products (see Table 3). The ideal fiber profile for enteral formula products is unknown, and there is no guidance on the ratio of soluble and insoluble fibers that children should consume. In addition to solubility, other fiber properties such as viscosity and fermentability must also be considered, which define the functional/physiological properties of the fiber. Recent findings show that there can also be complex interactions between different types or subsets of fibers. We need to distinguish between different fiber types and recognize that they may play a complex role. Certain fibers can be harmful during periods of active inflammation [87].

Although individual fibers may reduce the incidence of diarrhea and constipation, the use of a mixture of bulking and fermentable fiber has been suggested as a preferable approach particularly for long-term feeding. Similar physiological effects to those of a regular mixed diet may be seen with the consumption of mixed fibers or fiber blends, a prima facie plausible finding since they will more closely reflect the composition of the average diet [64]. Despite the lack of universal agreement, it has been proposed that soluble fiber should account for nearly 30% of the fiber blends, which mimics the ratio found in normal food [64]. Fiber blends can combine the benefits of fermentable prebiotic and non-fermentable fibers and can be used in oral nutrition supplements, and tube feeds. Fermentable prebiotic fibers promote the growth of healthy gut microbiota [64]. On the other hand, non-fermentable fiber within the fiber blend can improve stool consistency and mass [57]. It was suggested that homemade blended or commercial ‘real-food’ formulas have beneficial effects on GI symptoms, such as vomiting and abnormal bowel habit [88,89], which can be explained by the fact that they are loaded with a mix of fibers that improve GI tolerance. Although there are a variety of fiber blends on the market, further research is required to find the optimal fiber blend combinations and doses.

While constipation and diarrhea are easy to assess clinically, the assessment of gut microbiota is not part of routine practice in most centers.

7.3. Age- and condition-specific dosing for tube-fed children

The recommended daily fiber intake for *healthy children* is summarized in Table 1. However, there are no recommendations on the dose of fiber to use in tube-fed children with acute and chronic illnesses due to a lack of clinical data. It has been suggested to use a daily fiber intake comparable to that recommended for healthy children [1,69]; however, evidence to support this is lacking. It is unknown whether sick children require similar, higher, or lower fiber doses than healthy children. It is also unclear whether fiber requirements and tolerance may differ depending on the underlying condition and clinical status of the child.

Furthermore, the fiber content of most current enteral formulas does not match the fiber intake recommendations of healthy children and is also likely low for the potential needs of patients. The fixed amount of fiber present in enteral formulas does not allow for adjustment of the dose of fiber unless extra fiber is added separately. Dietary fiber should be introduced gradually on symptom-based approach. Based on clinical experience an estimated 10 g/day <3 years and >20 g/day for ≥14-year-old adolescents might be considered.

A multidisciplinary approach can help optimize nutritional care in complex patients. Further studies are required to investigate the ideal fiber dose in children requiring nutrition support.

7.4. Fiber-containing enteral formula as first-line nutritional therapy

The current evidence supports the use of dietary fiber in enteral feeding formulas as a first-line therapy for children who need nutritional support to prevent the occurrence of diarrhea or constipation and support gut microbiota. For children on a low-fiber diet, the fiber content of the enteral formula may need to be increased gradually to the target dose to allow a progressive gastrointestinal adaptation and reduce the risk of gastrointestinal intolerance symptoms.

7.5. Recommended feeding approach

Introducing a fiber-containing formula should be considered when initiating tube feeding. A stepwise process, especially in fiber-naïve patients, is advised. Children, including those receiving nutritional support, will benefit from consuming fiber from various sources. Previous studies suggest a potential benefit of adding soluble fiber in children receiving high-energy enteral feed [86]. Still, more studies are needed to discover more about the effect of the amount and mix of fiber, including soluble versus insoluble fiber, and the contribution of oral fiber intake. Patients should continue on the fiber-containing formula that they tolerate best. Because tolerance can change over time, monitoring child tolerance to the fiber-containing formula is recommended. Dietary fiber in children receiving enteral nutrition can be provided through a fiber-containing formula or by adding dietary fiber supplements. Fiber-containing formulas can prevent a recurrence, so continuation should be considered even after achieving clinical goals.

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Box1 Summary of Experts' Recommendations

Dietary fiber plays an important role in pediatric nutrition by supporting gut health and microbiome and promoting normal laxation. The current evidence supports using fiber in enteral formulas as first-line nutritional therapy. Nonetheless, practical guidance on the use of fiber-containing EN in the pediatric population is still lacking.

1) Who are the target patients for the enteral formula with fiber?

Fiber should be considered for all patients requiring enteral nutrition and can be gradually introduced from 6 months of age. Healthcare professionals should use their clinical judgment in specific cases where the use of fiber is poorly tolerated.

2) What type of fiber should be considered?

Several types of fibers have been used. Although individual fibers may reduce the incidence of diarrhea and constipation, the use of a mixture of bulking and fermentable fiber has been suggested as a preferable approach particularly for long-term feeding. Despite the lack of universal agreement, it has been proposed that soluble fiber should account for at least 30% of the fiber blends, which mimics the ratio found in normal food. The future, a more personalized approach to fiber may be advised.

3) How much fiber is recommended for tube-fed children?

There is no universal consensus on the dose of fiber to use in tube-fed children with acute and chronic illness due to a lack of clinical data. The fiber content of most current enteral formulas does not match the fiber intake recommendations of healthy children and the fixed amount of fiber present in enteral formulas does not allow to adjust the dose of fiber unless extra fiber is added separately. The current pediatric requirements for fiber intake should be considered as a reference both for healthy children and those who need nutritional support. Dietary fiber should be introduced gradually, especially in fiber-naïve children, with an individualized symptom-based approach.

4) Should tube feeding with fiber-containing enteral formula be considered a first-line nutritional therapy?

Current evidence supports the use of dietary fiber in enteral feeding formulas as a first-line nutritional therapy.

5) What is the ideal feeding approach?

The introduction of a fiber-containing formula should be considered in children requiring enteral nutrition. A progressive introduction of fiber is advised in children receiving fiber-free or low-fiber formula. Patients should continue on the fiber-containing formula they tolerate best, with fiber intake adapted to their tolerance, as there are no specifically defined contraindications. Long-term fiber intake might be recommended to prevent recurrence of GI problems.

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ORCID

Paolo Lionetti http://orcid.org/0000-0001-8029-3904
Eytan Wine http://orcid.org/0000-0002-3458-4142
Rinat Ran Ressler http://orcid.org/0000-0002-7071-0775
Gerard J. Minor http://orcid.org/0000-0001-8182-0104
Giles Major http://orcid.org/0000-0001-7944-3709
Boutaina Zemrani http://orcid.org/0000-0003-1963-388X
Frédéric Gottrand http://orcid.org/0000-0002-5290-0436
Claudio Romano http://orcid.org/0000-0001-8827-2091

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