Chicory root fibers – supporting a healthy gut microbiota and beyond.

Content

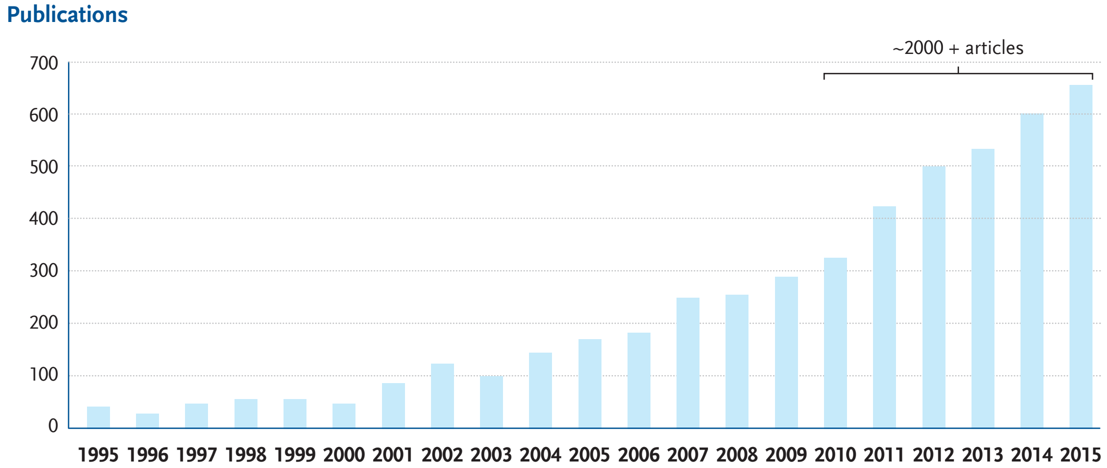
Your microbes at work to keep your gut flora healthy.

We are never alone. A vast number of microbes live within us, making up the human microbiota. In recent years, a growing number of research studies have focused on the link between these microbes and our health. It became clear that the role of our gut microbiota has reached importance far beyond gut health. Several factors can influence the balance of the gut microbiota. Prebiotics are among them and their beneficial effects will be discussed here.

The prebiotic concept: more relevant than ever.

The composition of the gut microbiota can be influenced by specific dietary components available for bacterial break down. The prebiotic concept describes food constituents that feed the good bacteria already existing in your gut which results in selective growth of these good bacteria and is linked to various health benefits. The prebiotic concept was first introduced by Gibson and Roberfroid in 1995 [1] and has been subject to intensive nutritional research ever since. It is well confirmed by scientists worldwide, including an expert panel under the umbrella of the International Life Science Institute who concluded in 2010 that "the prebiotic effect exists and is now a well established scientific fact". [2, 3] Prebiotic research has continued at a rapid pace with more than 2000 research articles published over the past five years* (see Figure 1).

Figure 1. Pubmed publications mentioning 'Prebiotic'



*Pubmed search

Prebiotics are non-digestible carbohydrates that pass intact through the small intestine and reach the large intestine undigested. There, they are fermented by bacteria in the saccharolytic fermentation mode (see more under "Prebiotic fermentation: To the gut and beyond!"), resulting in modifications in the gut microbiota composition by selective stimulation of the growth of bifidobacteria and lactobacilli; beneficial microorganisms that are part of the microbiota composition.

The most recent scientific definition of **prebiotics**, elaborated by the International Scientific Association for Probiotics and Prebiotics in 2008 (6th Meeting, London, Ontario) [4] describes prebiotics as follows:

"A dietary prebiotic is a selectively fermented ingredient that results in specific changes in the composition and/or activity of the gastrointestinal microbiota, thus conferring benefit(s) upon host health."

In order to be classified as a prebiotic, certain criteria need to be fulfilled [5]:

- Resistance to hydrolysis and absorption
- Fermented by intestinal microbiota
- Selective stimulation of growth and/or activity of intestinal bacteria associated with health and disease

The scientific substantiation should be based on state-of-the-art techniques on measuring bacterial counts and should be based on human data. In vitro and animal studies alone do not provide enough substantiation – human studies are needed.
There are only three proven prebiotics worldwide: chicory root fiber, galacto-oligosaccharide (GOS) and lactulose which are described in more detail below.

1. Chicory root fiber (synonyms: inulin, shorter chain inulin (= oligofructose = fructo-oligosaccharides (FOS)), longer chain inulin, mixtures of shorter and longer chain inulin)

- Non-digestible in small intestine and fully fermentable in large intestine
- Made up of oligo- and polysaccharides: inulin-type fructans
- Plant-based natural dietary fiber
- Extracted from the chicory root by hot water
- Extensively researched for more than 20 years; beneficial health effects demonstrated by numerous human intervention studies

2. Galacto-oligosaccharide (GOS)

- Non-digestible in small intestine
- Qualifies partially as dietary fiber because of non-digestibility (degree of polymerization DP≥3 can be counted as dietary fiber)
- Synthetically produced oligosaccharides of the form Glu α1–4[βGal1-6]n (η=2–5) produced from lactose (animal origin) by using β-galactosidase
- GOS data base on human intervention studies addressing health benefits is still weak

3. Lactulose

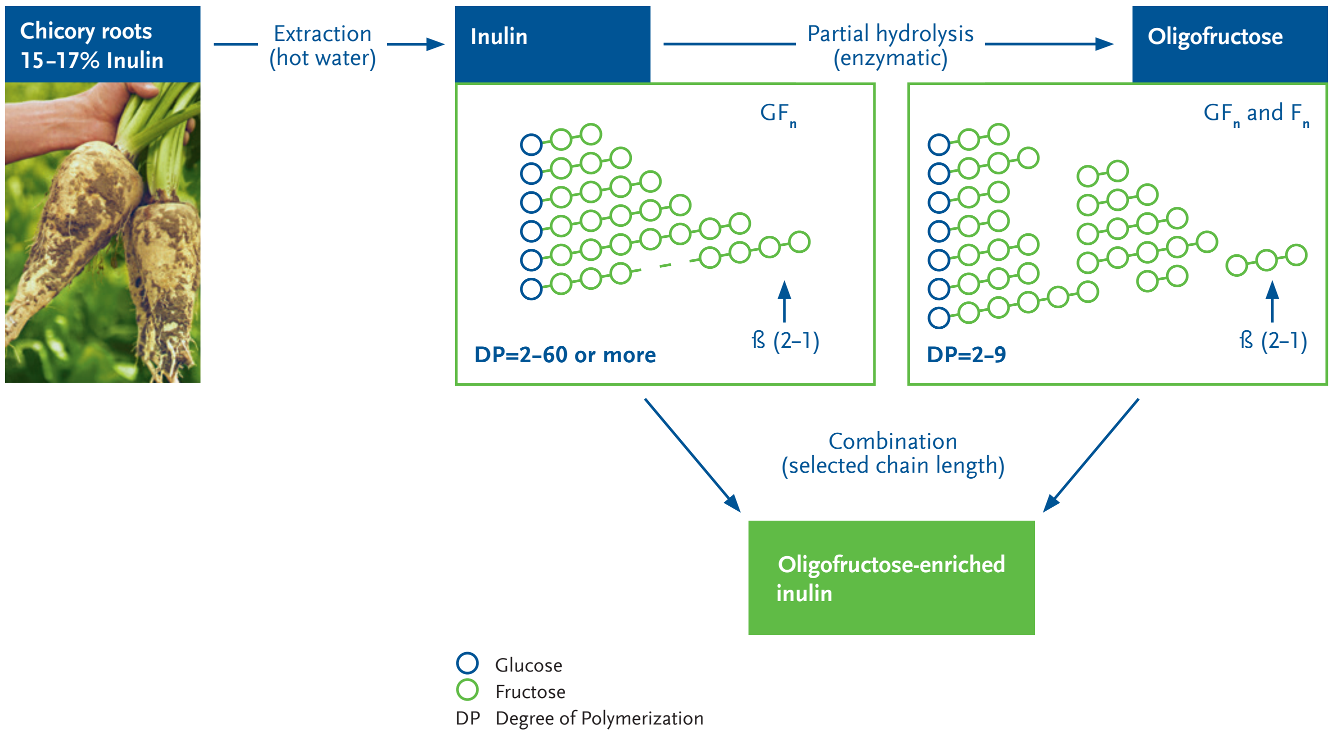
- Disaccharide that is non-digested in small intestine, reaching the large intestine as substrate for microbiota
- As a disaccharide it is not classified as a dietary fiber but as a sugar
- Synthetic disaccharide, produced commercially by isomerization of lactose (animal origin)
- Mostly applied in pharmaceutical industry as a laxative

Some limited data from other non-digestible carbohydrates are available demonstrating some prebiotic potential in vitro. More research on those "candidates" is needed to demonstrate the effect in human intervention studies with sufficient statistical power and using state-of-the-art detection methodology.

Chicory root fiber – a proven prebiotic.

Chicory is a perennial plant of the dandelion family that grows in its wild form in many areas of the country. The root of the chicory plant stores the carbohydrate energy known as inulin. Inulin is also a storage carbohydrate in onions, bananas, artichokes, yacon and more. Inulin has been consumed since ancient times. In the time of 'gatherers and hunters' the daily intake was calculated by paleontologists at about 135 g per day. [6] While the chicory root today is no longer a regular part of our diet, its fibers (**inulin** and its short-chain form, also called **oligofructose**) still are and they are used in many fiber-enriched food products. The chicory plant today is grown by farmers for the mild extraction of inulin from the root by hot water. Chicory root fiber is an umbrella term for long- and short-chain inulin. The short-chain inulin, aka oligofructose or fructose-oligosaccharide (FOS) is derived from inulin with an enzyme that naturally also exists in the chicory root. This process occurs in the mature chicory root. The chain length of inulin may vary to make it more versatile for different food applications. The degree of polymerization (DP) is used to describe the chain length. For instance, longer chains (DP≥10) give a more creamy mouthfeel, making it ideal for fat reduction, while the shorter chains (DP=2–9) give a slightly sweet, clean taste and therefore are often used for sugar reduction in food products. Dedicated combinations of shorter and longer chain inulin can also be made.

Figure 2. The process from field to chicory root fiber



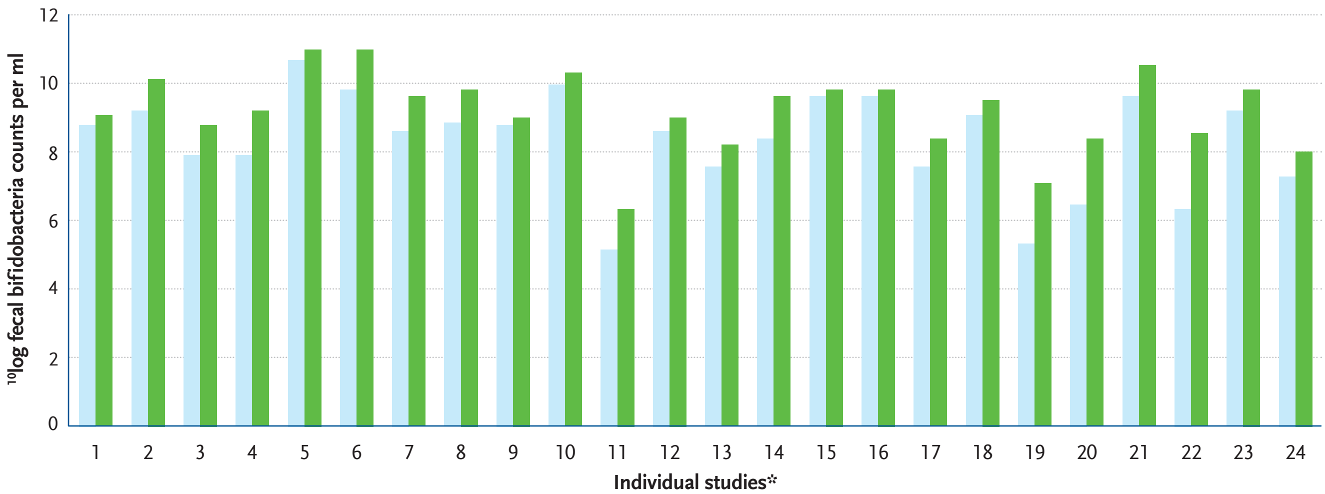
Chicory root fibers are natural, only extracted from chicory root with pure hot water.

The prebiotic effect – bifidos as a marker for a healthy microbiota.

Interest in the prebiotic effect on our gut microbiota composition continued to grow which led to numerous studies in infants, young children and adults. Research applying state-of-the-art techniques confirmed a selective increase of beneficial bacteria, using bifidobacteria and lactobacilli as well as established biomarkers, after inulin and oligofructose consumption in human intervention studies.

The following figure demonstrates the totality of chicory root fiber data and their prebiotic effect in adults. 24 human trials were carried out with chicory root fibers showing that inulin and oligofructose selectively stimulate the growth of bifidobacteria in the large intestine. **High levels of bifidobacteria became a marker for a healthy microbiota composition.** [2]

Figure 3. Significant increase of bifidobacteria in adults from 5 g/day, inulin and/or oligofructose



*List of references is available upon request

Prebiotics are different to probiotics. **Probiotics** are currently defined as live microorganisms which, when administered in adequate amounts, confer a health benefit on the host. The vast majority of all studied and commercially available probiotics today are bifidobacteria and lactobacilli. There are certain guidelines for probiotics. They need to survive the gut passage to the large intestine despite the acidity in the stomach. Each probiotic strain should be clearly characterized which is important for its safety assessment. In addition, the health benefits need to be established in human studies, specifying the quantity of the microorganism that leads to the benefit. [7] Probiotics are added to food, often dairy products, or taken as food supplements to introduce additional amounts of good bacteria into the gut. However, probiotics do not become natural inhabitants of the large intestine, they are “in transit” and excreted through the feces.

Prebiotics, on the other hand, nourish the good bacteria that are naturally present in the gut as well as the probiotics and offer a way of selectively stimulating the growth of the good bacteria.

A mixture containing probiotics and prebiotics is called a **synbiotic**. It is a living organism (probiotic) that is combined with its preferred ‘food’ (prebiotic) in order to increase the survival rate of the organism in the intestine.

Microbiota, digestive health and well-being – health benefits linked to chicory root fiber.

Scientists have learned of the importance of a well-functioning colon for our health and well-being. The colon is responsible for nutrient and water absorption as well as waste secretion and acts as a **mucosal barrier** between the external and internal environments. Our gut has its own nervous system. It's our **"second brain"**, regulating peristalsis and the release of digestive enzymes, just to name a few. The intestine is a significant regulator of our **immune system**, about two-thirds of all immune cells of our body are based there. In addition, our colon is the **largest hormone producing organ** of the body, e.g. ghrelin, GLP-1, PYY. Its living microorganisms, our microbiota, can produce thousands of different biologically active substances that may be absorbed and reach organs like the liver, kidneys and also the brain. In fact, an increased consumption of prebiotics can positively influence the microbes in our gut, which has implications not only for our gut health but far beyond.

Prebiotic fermentation: "To the gut and beyond!"

Not all dietary fibers are the same. **Fermentation of fibers is the key to many health benefits.** Some fibers, like cellulose are not fermentable, lead to increased bulk in the intestine and are excreted through the feces. Others, are partly fermentable only. While they are fermented by gut bacteria, they do not necessarily increase the population of good bacteria, like bifidobacteria. Chicory root fibers, like inulin and oligofructose, are completely fermented in the colon by gut bacteria and lead to a selective increase in bifidobacteria. Bifidobacteria and some other bacteria strains break down chicory root fiber by saccharolytic fermentation which leads to the production of short-chain fatty acids (SCFAs), i.e. acetate, propionate and butyrate. [8, 9]

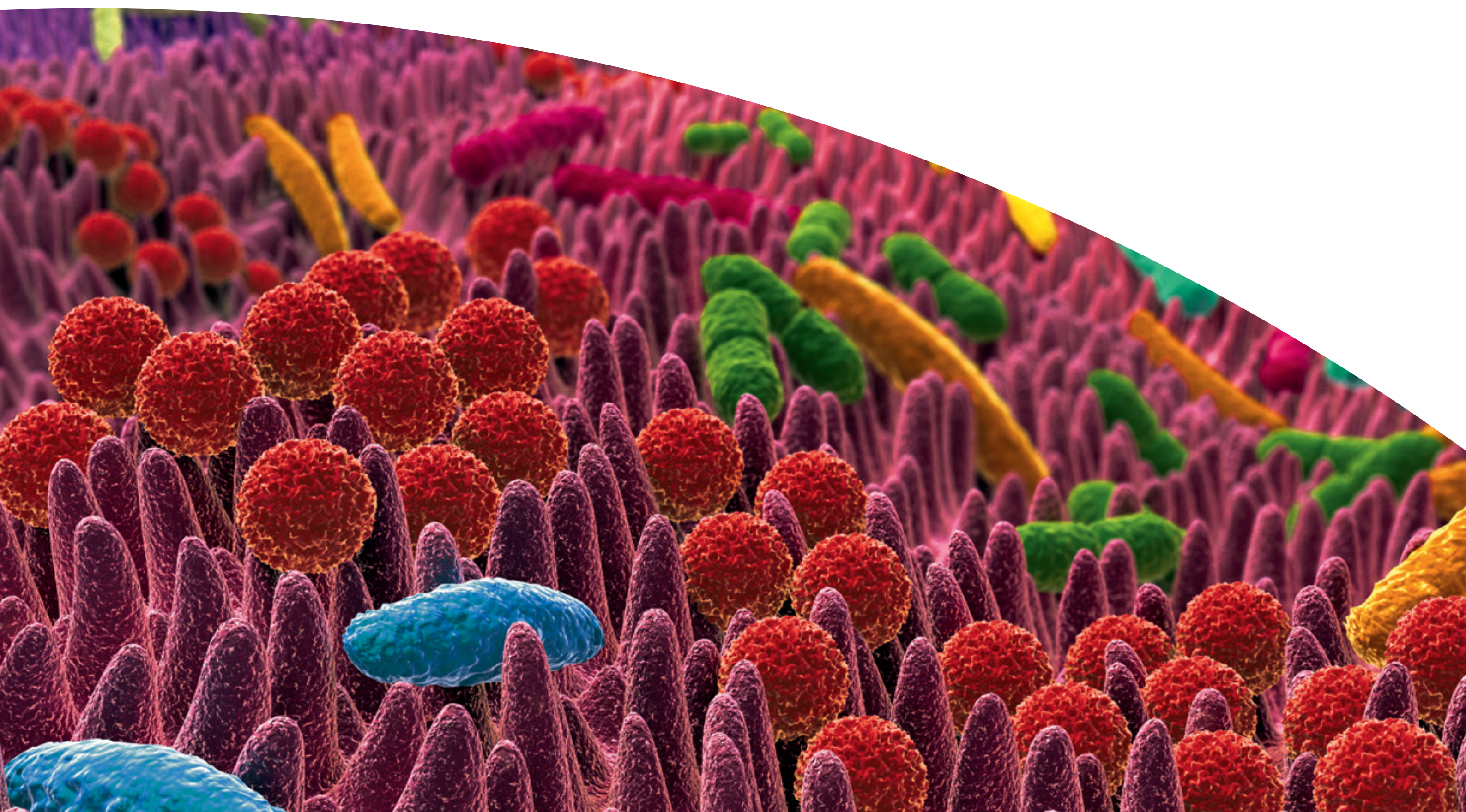
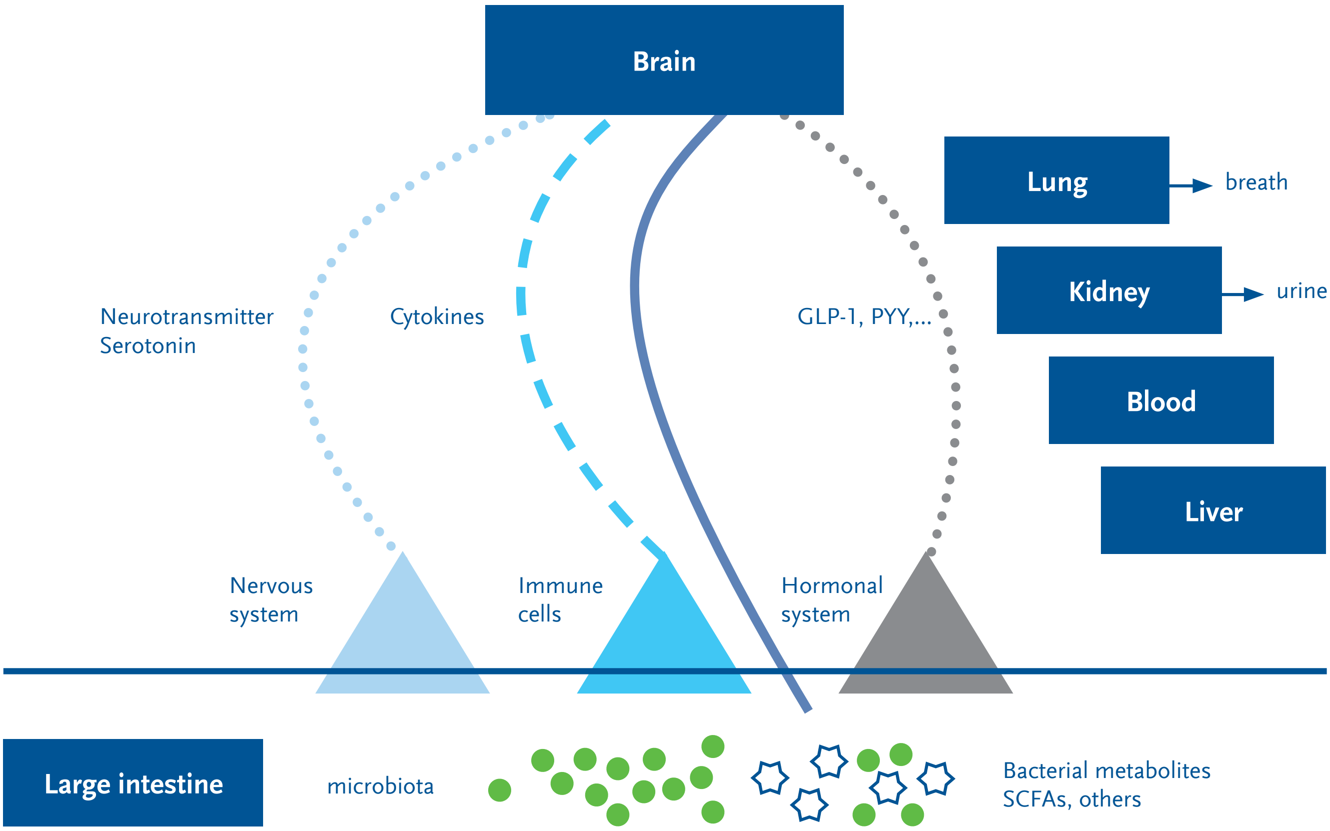


Figure 4. Prebiotic fermentation – benefits to the gut and beyond

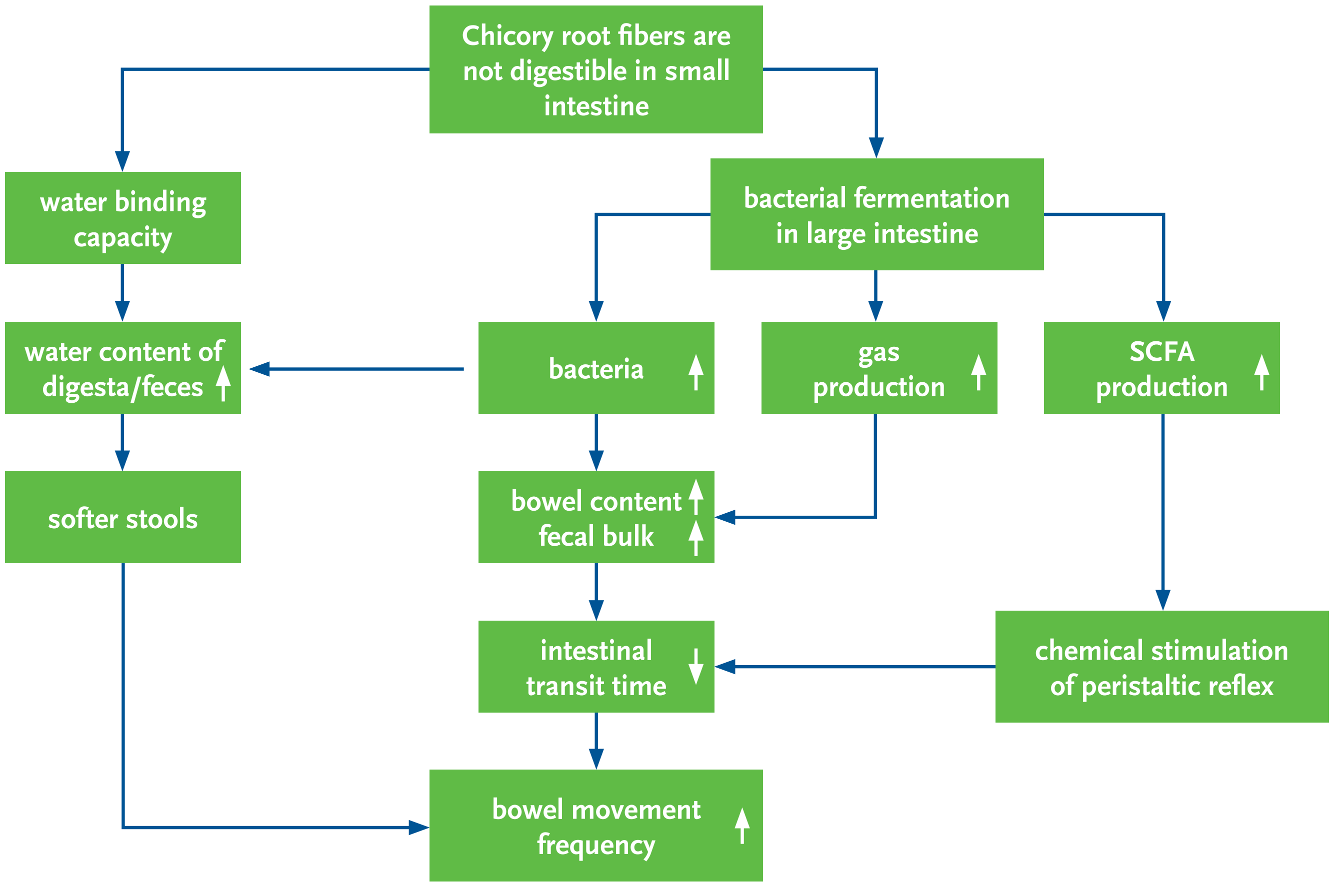


These SCFAs have several beneficial effects, helping to create a more acidic environment in the colon and therefore enhancing calcium absorption (specifically related to Oligofructose enriched inulin as seen in section "For stronger bones: Give your bones a treat"), nourishing the intestinal mucosa and inhibiting pathogens. SCFAs also support the growth of the microbiota, stimulate the peristaltic reflex which results in more frequent bowel movements and "cross-talk" with the brain to signal satiety. Particularly acetate appears to cross the blood-brain barrier and reaches the hypothalamus to influence the hunger/satiety center by reducing appetite and subsequently food intake, as demonstrated in scientific studies done with oligofructose-enriched inulin. [10] Research in this area is promising and opens up important new possibilities for chicory root fiber to support healthy nutrition in the light of obesity and diabetes developments. [11] With adequate amounts of prebiotic chicory root fiber and the related support for the beneficial bacteria (primarily bifidobacteria and lactobacilli), the more favorable saccharolytic fermentation dominates. In contrast, proteolytic fermentation (protein fermentation) and the related microbiota which can produce potentially harmful compounds, such as carcinogens and co-carcinogens is suppressed. Overall we can say that the consumption of **chicory root fibers and the complete prebiotic fermentation leads to a positive shift in the gut microbiota composition providing many health benefits.** [2, 12]

Digestive health, a key predictor of well-being.

Digestive health problems, including bowel irregularity and constipation are a common problem in our society and have far reaching effects on our quality of life and overall health. **The consumption and following fermentation of chicory root fiber can give relief**

Figure 5. Mechanisms that show how chicory root fibers gently increase bowel regularity

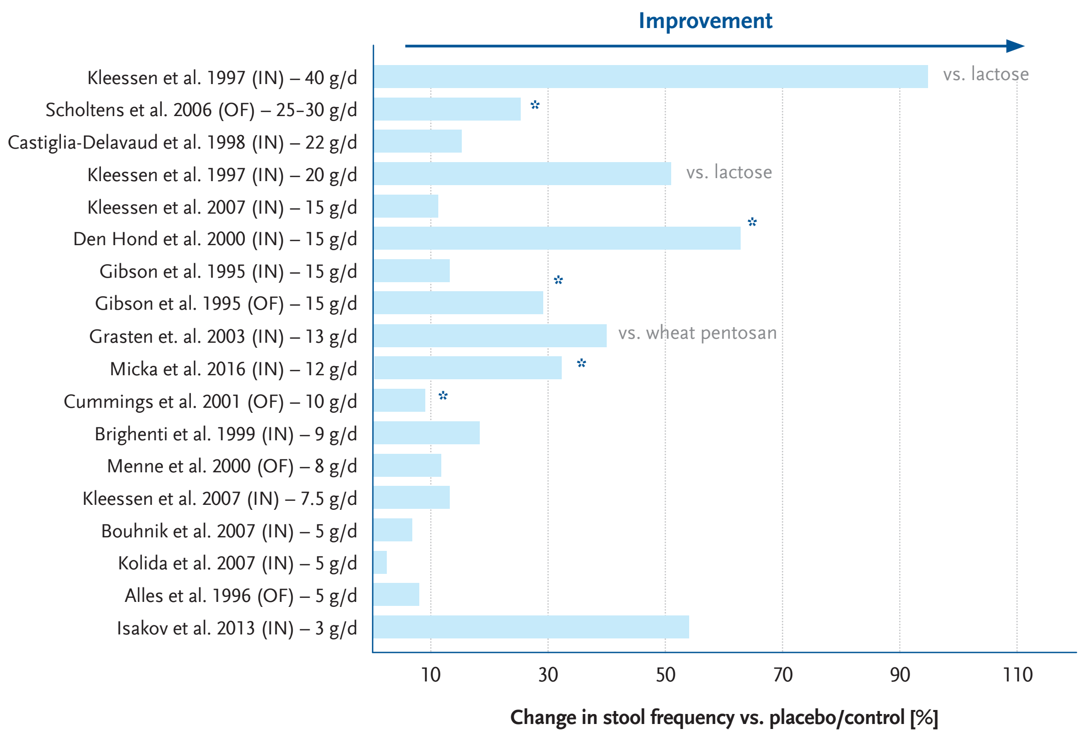


The prebiotic fermentation of chicory root fibers by the microbiota leads to break down products (SCFA) and metabolites which are signals and promote the production of the neurotransmitter serotonin, a key regulator of the motility of the gastrointestinal tract. [14] This causes the gut peristaltic to "move" and thus supports the normal gut function that leads to relief. Stool softening occurs as some more water stays in the large intestine instead of being re-absorbed so that straining can be avoided. The increase in bifidobacterial counts also leads to an increase in biomass, i.e. an organic and natural increase in fecal bulk and keeps the feces softer. All this together helps to avoid hard stools and constipation and supports normal bowel function with respect to a slight but significant increase in stool frequency per week.

In addition to the EFSA evaluation, a meta-analysis of five intervention studies demonstrated significant effects of inulin on stool frequency, stool consistency and transit time. [15]

Overall, improvement of digestive health by supporting regularity due to chicory root fibers, inulin and oligofructose, were demonstrated in over 24 human studies ranging from children to older adults (see Figure 6). It can be concluded that with a daily intake of 8–12 g/day (intake on several occasions during the day), the positive effect on regularity with chicory root fiber can be achieved.

Figure 6. Effects of chicory root fiber on stool frequency



*significant effect vs. placebo/control (p<0.05)

As mentioned before, the large intestine is the place where two-thirds of all immune cells are based. For this reason, researchers assume a close link between bifidobacteria and the support of inner resistance. The fermentation of chicory root fiber creates a more acidic environment in the large intestine keeping acid-sensitive pathogens at bay, nourishing mucosa cells, thickening the mucous layer and maintaining an intact gut barrier. [16] Cummings demonstrated in his study design that those at risk of developing travelers' diarrhea may benefit from oligofructose consumption. Healthy subjects at risk of travelers' diarrhea were given 10 g of oligofructose per day. They experienced a small significant increase in stool frequency, a (non-significant) decrease in diarrhea episodes and a significantly improved sense of well-being. [17]

What about FODMAP in IBS patients?

FODMAP stands for "**f**ermentable **o**ligosaccharides, **d**isaccharides, **m**onosaccharides **a**nd **p**olyols" that are poorly absorbed short-chain carbohydrates, such as, GOS, FOS, lactose, fructose, sugar alcohols like sorbitol and many other non-digestible carbohydrates in fruits and vegetables. It is a restrictive diet that basically leads to the exclusion of fruits and vegetables from the diet. FODMAP components are fermented by the microbiota and this process is believed to be the cause of gastrointestinal complaints, i.e. bloating, gas, diarrhea, constipation and cramping in sensitive patients. A diet low in "FODMAP" compounds is therefore often recommended for patients that feel to be affected, especially those with irritable bowel syndrome (IBS).

As is the case for any extreme diet, pros and cons need to be looked at and at the same time the scientific proof for the underlying hypotheses needs to be provided. A lot of questions pop up in this case. Without proper monitoring by a dietitian, a low FODMAP diet can be unbalanced, limiting fiber intake and consumption of fruits and vegetables – this leads to unhealthy nutrition. Only if the subjective feeling of well-being is significantly improving and gastrointestinal complaints disappear on long-term, could this special nutrition be a compromise for affected patients.

The saccharolytic fermentation is the preferred pathway to support health. The absence of saccharolytic fermentation triggered by the low FODMAP diet could cause more harm than good. There is often a belief that the production of SCFA and the production of hydrogen and carbon dioxide, that may occur depending on the bacterial composition, lead to subjective unacceptable gastrointestinal complaints. Bifidobacteria are SCFA producers, but not gas producers – unlike some other bacteria. However, a vast majority of the SCFA and gases are absorbed in the intestine and metabolized or excreted via the breath. The body can handle this very well, even in sensitive people. In fact, scientific evidence has shown that (soluble) fibers help reduce global symptoms of IBS and abdominal pain. [18–20] It is questionable if the scientific basis is strong enough to conclude beneficial effects of low FODMAP diets in IBS patients. [21] **Current data shows that at least chicory root fiber is well-tolerated by IBS patients** at normal daily intakes. [22, 23]

As a proven prebiotic, chicory root fiber contributes to support a healthy gut environment and relieves constipation in some IBS patients due to improved bowel regularity and therefore supports a healthy human gut microbiota. To conclude, at the end of the day, what counts is the patient's feeling of well-being.

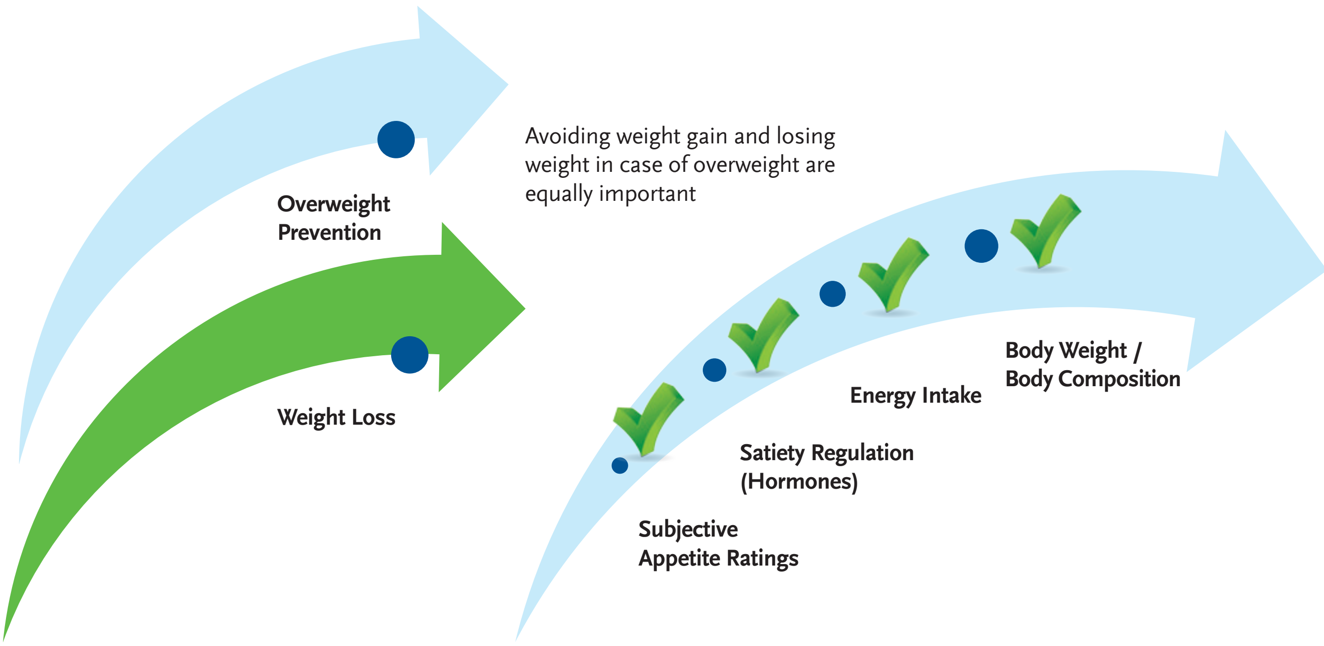
Feeling the digestion is OK!

In most societies around the world, including the United States, only about half of the dietary fiber that should be eaten is indeed consumed. In order to bridge the fiber gap, a higher fiber intake is needed and recommended as seen in the recently issued Dietary Guidelines for Americans 2015–2020. [24] A higher intake of fiber leads to more activity in the gut, you can feel that "something is happening", e.g. from an increase in bowel movements per week, softer stools (but no diarrhea) or possibly slightly more gas production compared to a diet with less fiber intake. Feeling your gut work is normal and the reason why we increase our fiber consumption in our diet. As health care professionals, it is important to bring this healthy body perception back to the consumer. Our gut is not "lazy and silent" anymore but actively working and fermenting the fibers, creating all the health benefits we get from fiber. Everyone's experience is different and therefore, fiber intake should be individually adjusted. We should increase fiber intake gradually to give our microbiota time to adjust.

Chicory root fiber influences the path towards a healthy body weight.

The prevalence of overweight and obesity has become a leading health concern worldwide, reaching epidemic levels. Supporting weight loss and avoiding weight gain is equally important. One of the strategies to support weight management focuses on the development of healthier food choices. Besides the benefits on digestive health as just illustrated, chicory root fiber has gained more and more attention regarding their supporting role in helping to eat less, naturally. Chicory root fiber has supporting scientific evidence in animal and human intervention studies on all stages of the scientific "ladder to success" in the weight management approach (see Figure 7.).

Figure 7. Chicory root fiber influences body weight



The mechanism behind this is related to the prebiotic fermentation of chicory root fiber in the colon and the subsequent formation of SCFAs (acetate, propionate, butyrate and lactate). These SCFAs influence appetite regulation and food intake by triggering a release of the gut hormones like GLP-1 and PYY. Both hormones are secreted (by L-cells) at the end of the small intestine and in the large intestine. They stimulate glucose-dependent insulin secretion, inhibit glucagon release in the pancreas and gastric emptying in the stomach as well as directly suppress appetite in the brain. [10, 28, 29]

Further research on human data suggests that **chicory root fiber intake helps you to eat less calories naturally**. A systematic review of 26 intervention studies confirms an increased self-reported feeling of satiety after chicory root fiber supplementation. [30] Results from an isocaloric study in ten healthy (normal to slightly overweight) adults show that people consumed about 5% less calories with 16 g of oligofructose added to their diet compared to the control group. [31]

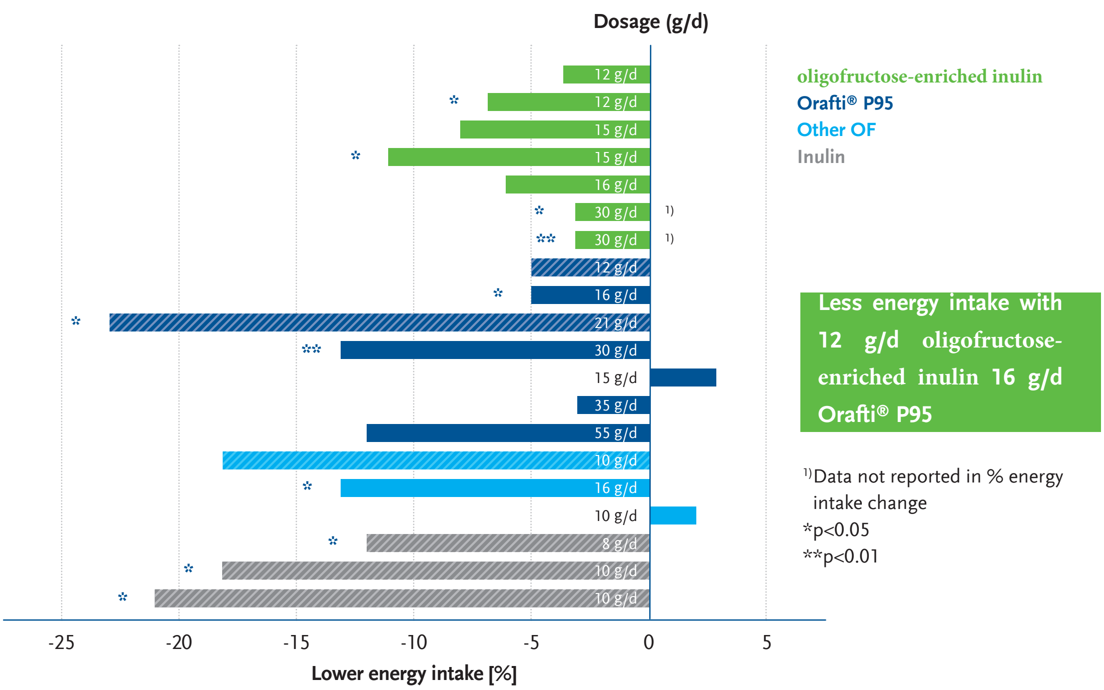
These effects were confirmed in a study from Parnell and Reimer where 21 g of oligofructose per day was given to 48 healthy, overweight adults for three months. As a consequence, the oligofructose group had a significantly reduced energy intake and lost body weight while the control group gained weight. Weight loss was primarily associated with reduction of trunk fat mass. The study participants receiving the oligofructose supplementation also experienced suppressed ghrelin and higher PYY levels increasing the satiety feeling. [32]

Beneficial effects of chicory root fiber supplementation on body weight and body composition were also confirmed by the group of Prof. Reimer in Canadian overweight and obese children and U.S. adolescents during growth. In a double-blind, randomized parallel study, 42 overweight and obese children, 7–12 years old, consumed 8 g of oligofructose-enriched inulin (a dedicated 50/50 combination of shorter and longer chain inulin) per day for 16 weeks. The results showed that subjective ratings of appetite and fullness improved, ad libitum energy intake at a breakfast buffet occasion dropped by about 200 calories (significant in the older age group 11–12 years), BMI and body fat mass decreased, IL-6 (a marker for overweight- and obesity-related inflammation) dropped significantly and the fecal flora composition significantly increased counts of bifidobacteria. [33] Based on Prof. Raylene Reimer's research, she concluded that:

"The intake of [BENEO's] prebiotic fiber ... [is] one more tool to use in the obesity epidemic."

The bar chart below illustrates the published studies on the effects of chicory root fibers on energy intake. Energy intake (caloric intake) is a strong parameter when assessing the strength of the data for weight management support. It is stronger than subjective appetite ratings and stronger than measurements of hormonal changes although those two elements are important "steps" on the ladder of weight management (see Figure 7).

Figure 8. Chicory root fibers reduce energy intake in adults



Patterned bars represent supportive evidence from self-reported data or discontinued fiber intake

Chicory root fibers help people eat less over time.

Bringing your blood sugar under control.

Diabetes has become a global health problem with an increasing prevalence year after year. In the U.S., 29.3 million people are diagnosed with diabetes, almost 10% of the population. [34] In 2012, 86 million American adults had prediabetes, more than 1 out of 3. [35]

Chicory root fiber intake results in a significantly lower blood sugar and insulin response while increasing the fiber content without compromising the taste. These effects were confirmed at a 20% sugar replacement as the lowest measured dose. EFSA evaluated the data which resulted in a positive opinion and an approved health claim in May 2016 on the reduction of postprandial glycemic response from non-digestible carbohydrates, like chicory root fiber. [36] Furthermore, studies with oligofructose-enriched inulin supplementation demonstrated that body weight, insulin sensitivity and glucose homeostasis were improved in pre-diabetic subjects consuming 30 g of oligofructose-enriched inulin per day for six weeks. The results were independent of lifestyle and not seen in the control group who ingested cellulose instead of inulin. To emphasize again, the prebiotic fermentation due to chicory root fiber and its influence on GLP-1 as a regulating gut hormone is regarded as the key benefit in the context of blood sugar management support. oligofructose-enriched inulin resulted in a beneficial enhancement of early-phase insulin secretion in response to a meal, which is considered to be of particular relevance for people at risk of developing type 2 diabetes mellitus. [37, 38]

A systematic review of 26 intervention studies showed that prebiotic supplementation with chicory root fibers significantly reduced postprandial glucose and insulin concentrations. [30]

These data encourage the use of chicory root fibers as an approach to reduce blood glucose and insulin levels in the diet of people wanting to improve the blood glucose response in prevention and management of glucose tolerance impairments.

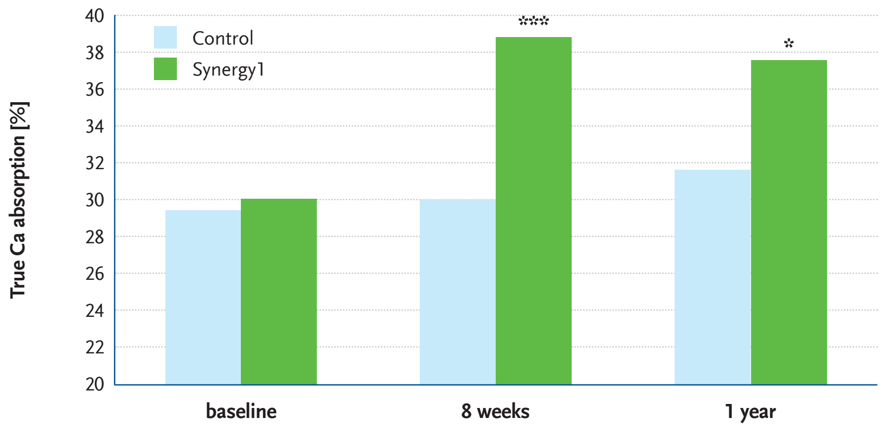
For stronger bones: Give your bones a treat.

Osteoporosis is a chronic and progressive disease leading to low bone mass, reduced bone density and reduced bone quality with a consequently higher risk of fracture. It is the second leading health care problem after cardiovascular diseases according to the World Health Organisation (WHO). Approximately 200 million people suffer from osteoporosis worldwide. In the U.S., around 54 million adults age 50 and older are affected by osteoporosis and low bone mass. [39] Sufficient calcium intake and absorption is the key to prevent osteoporosis. Since only about 30% of the dietary calcium is absorbed in the body, it is even more important to make the best use of all the calcium which is available in our diet. Our body builds bone mass during childhood into the mid-twenties where the peak bone mass is reached. After that, bone mass decreases with an even faster demineralization process in women after menopause. It is therefore important to maximize peak bone mass during adolescence in order to reduce bone loss later in life.

More than twelve human intervention studies have illustrated that **chicory root fiber increases calcium absorption.** The unique combination of longer chain inulin and shorter chain inulin (oligofructose/FOS), aka oligofructose-enriched inulin, has been shown to change the environment of the whole length of the large intestine so that the complete large intestine environment is influenced to promote calcium absorption, i.e. a new place of absorption in addition to the small intestine was made available due to this and the bioavailability of calcium in the normal diet is significantly increased. The mechanism behind is that SCFAs that are produced from chicory root fiber fermentation increase calcium absorption by decreasing the pH in the colon, stimulating growth of mucosal cells to increase the absorptive surface, enhancing intracellular permeability and indirectly stimulating the production of calcium-binding proteins. [40] These beneficial effects of oligofructose-enriched inulin have been demonstrated irrespective of food matrix and have no negative effect on other minerals and vitamin D levels.

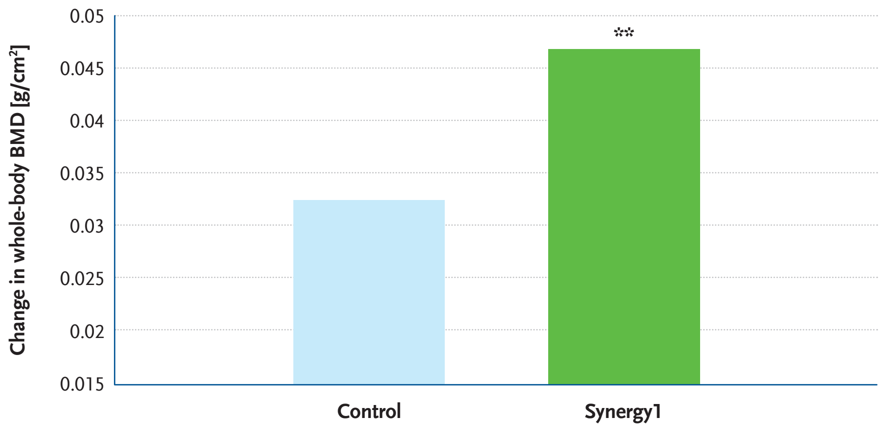
A one year intervention study, conducted at the USDA Children's Nutrition Research Center at the Baylor College of Medicine in Houston, TX supplied 8 g of oligofructose-enriched inulin per day to 100 adolescents to examine long-term effects of chicory root fiber on calcium absorption and bone health. After one year, the oligofructose-enriched inulin group had significantly higher calcium absorption and greater bone mineral density (BMD) compared to the control group, i.e. it was demonstrated that the additional calcium absorbed indeed reached the bones. This study is one of a kind in demonstrating long-term benefits of oligofructose-enriched inulin for bone health. [41] Results on true calcium absorption and BMD are shown in the figures below.

Figure 9. True Ca absorption after oligofructose-enriched inulin intake



*p < 0.05 vs. control, ***p < 0.001 vs. control

Figure 10. Changes in whole-body bone mineral density (BMD) after supplementation with oligofructose-enriched inulin



**p = 0.01 vs. control

What about the little ones? Benefits of chicory root fiber intake in infants and small children.

The development of the gut microbiota is a critical and essential process early in life as it may impact later health outcomes by potentially reducing the risk of obesity, inflammatory bowel disease, allergies and certain behavioral disorders in adulthood. [42]

Importance of early colonization.

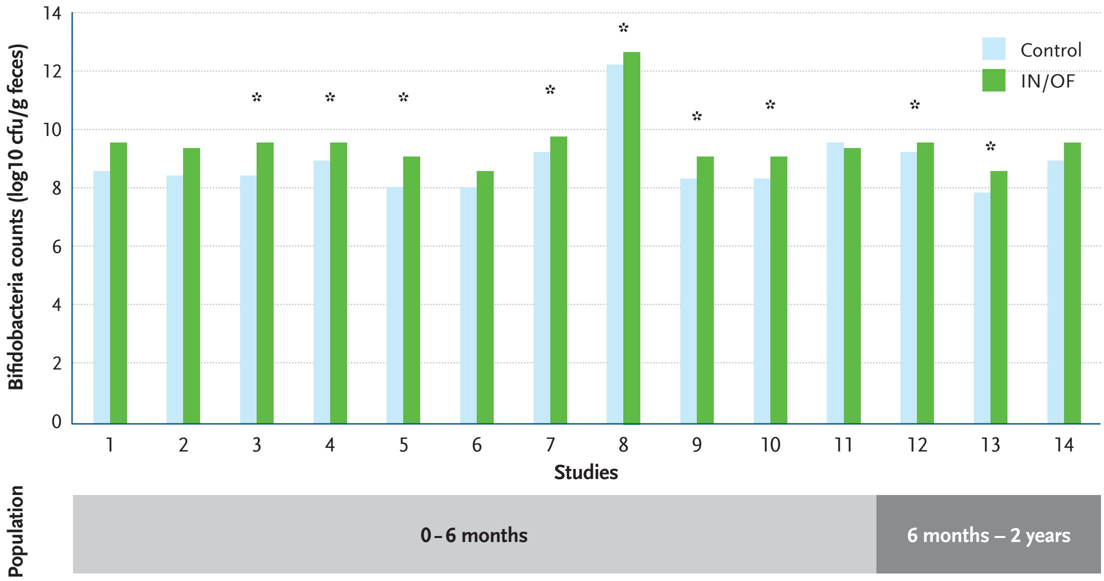
Babies are born with an (almost) sterile gastrointestinal tract which is quickly colonized by microorganisms after birth. Important factors that affect bacterial colonization are the mode of delivery, prematurity, excessive use of antibiotics during the perinatal period, mother's microbiota and type of feeding (breastfeeding). Around the age of 2–3 years, the microbiota composition becomes more stable and begins to resemble that of an adult.

Bifidobacteria are the dominating microorganisms in the gut microbiota of breastfed infants independent of the region they were born. High levels of bifidobacteria in breastfed infants have been associated with reduced counts of potentially harmful bacteria like E. coli and others. Human milk oligosaccharides (HMOs) are the first prebiotics in the diet of a baby. They are a complex group of more than 200 identified non-digestible

oligo- and polysaccharides found in human breast milk and are also described as the “bifidofactor” of human breast milk. They greatly influence the infant’s microbiota composition. Breastfeeding is the best nutrition for babies and associated with a protective role in the development of a number of diseases later in life. When breastfeeding is not possible, the baby should nevertheless get as close as possible to the advantages of breastfeeding. This is the reason why inulin and oligofructose are part of infant and follow-on formulas around the world.

Figure 11 reflects the impressive amount of 14 human intervention studies with infants and small children that demonstrate that supplementing infant formulas or follow-on formulas with chicory root fibers (oligofructose/FOS, long-chain inulin, mixtures of shorter and longer chain inulin including oligofructose-enriched inulin were used in those studies) increase the amount of bifidobacteria which positively affects the infant’s microbiota and brings it closer to that of breastfed babies.

Figure 11. Prebiotic data with chicory root fibers in infants and small children



*List of references is available upon request

A study conducted in Belgium analyzed the influence of chicory root fiber on the gut microbiota composition of 62 healthy infants. The babies received four different supplemented formulas for 28 days. The numbers of bifidobacteria significantly increased in the group with chicory root fiber addition (oligofructose-enriched inulin, a prebiotic mix of inulin and oligofructose) and were comparable to that of breastfed infants compared to the control group. [43]

Closa-Monasterolo et al. led a study to address the prebiotic effect as well as safety of chicory root fibers in newborns. 252 healthy infants received a formula enriched with oligofructose-enriched inulin or a control formula for the first four months of life. The results showed a higher increase of bifidobacteria in the oligofructose-enriched inulin group versus infants fed the control formula. The microbiota composition of the oligofructose-enriched inulin infants was comparable to that of breastfed infants. Also, all infants experienced normal growth and development patterns. Tolerance and formula acceptance was very good confirming the safety of the oligofructose-enriched inulin-containing formula. [44]
Dr. Closa-Monasterolo concludes:

“A 0.8 g/dL oligofructose-enriched inulin-supplemented infant formula during the first four months of life is safe and effective, promoting a gut microbiota closer to that of breastfeeding.”

Healthy bowel habit, more important than ever.

One of the main concerns of mothers is their baby’s stools as this is related to their overall health and well-being. There are many things that can affect an infant’s bowel movement, such as nutrition, age and different feeding habits. There is a major difference in stool frequency and consistency of breastfed compared to formula fed infants. Breastfed babies have more frequent and softer stools, often even liquid stools because of the HMOs in breast milk. Concentration of HMO in mature breast milk is reported to be at approximately 12–14g/L [45, 46], in the breast milk of the first days concentrations of 20–24g/L are reported. Formula fed babies have often harder stools and constipation is an issue. In order to promote a healthy bowel habit, also for milk-based formula eating babies, prebiotics are added to infant formulas to get closer to a breastfed situation. Supplementing formulas with inulin and oligofructose from chicory root have been shown to benefit by providing soft but not liquid stools.

The four week study led by Veereman-Wauters et al. on newborns illustrated significantly softer stool consistency when adding oligofructose-enriched inulin to the formula versus the control group. Overall, breastfed babies had the softest stools while the control group experienced the hardest bowels. No impact was shown on stool frequency. [43]

In the study conducted in Spain by Closa-Monasterolo et al., healthy infants receiving a formula enriched with oligofructose-enriched inulin had significantly higher stool frequency and softer stools compared to controls, moving them closer to infants that were breastfed. In addition, the microbiota composition of the
oligofructose-enriched inulin infant group was closer to that of the breastfed babies, clearly demonstrating the safety and effectiveness of a formula supplemented with oligofructose-enriched inulin. [44]

One of the most common gastrointestinal complaints in children is chronic constipation. BENEO therefore conducted a pilot study in 17 constipated children (2–5 years old) to investigate the effects of chicory root fiber supplementation on bowel regularity in this group of children. Those who received the prebiotics had significantly softer stools compared to the control group. [47]

Increased inner protection.

The time period right after birth is important for programming the immune system. With regards to this, nutrition during pregnancy and during early postnatal life plays an important role. In addition, the newborn has an immature immune system that increases its susceptibility to infections. This vulnerability is even more important in formula fed infants. A balanced gut microbiota composition with increased levels of bifidobacteria seems to benefit the immunity of infants. Since higher levels of bifidobacteria are found in breastfed infants, a similar microbial colonization should be encouraged for formular-fed infants. Adding prebiotics to the formula is a step in the right direction.

Through their effect on the growth of bifidobacteria, thereby resembling the benefits of breastfeeding on the maturation of the immune system, prebiotics may offer additional protection and strengthen the mucosal barrier that can be essential for a newborn's immune system, in particular if formula fed.

A six month study conducted on 123 healthy children (4–24 months old) in day care centers focused on the effect of oligofructose-enriched cereals on gastrointestinal markers related to health and well-being. The babies in the oligofructose group experienced less general gastrointestinal symptoms, like vomiting, regurgitation and general discomfort compared to the control group. Oligofructose supplementation also showed statistically significant reduced symptoms associated with diarrhea, such as fever and physician visits. The control group had a greater absence from day care centers and a higher usage of antibiotics compared to children receiving the prebiotic supplementation. [48]

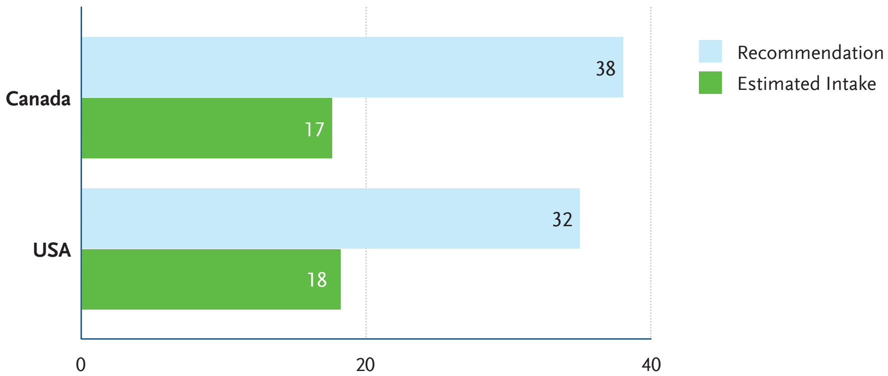
A review and meta-analysis of five randomized controlled trials assessed the effects of prebiotics (including oligofructose) in the prevention of acute infectious diseases in 0–24 months old babies. The results showed that the number of infectious diseases requiring antibiotic therapy decreased with supplementation of prebiotics. From studies available to date, we can assume that prebiotics may be effective in reducing the rate of overall infections in infants and children aged 0–24 months. [49]

Concluding remarks

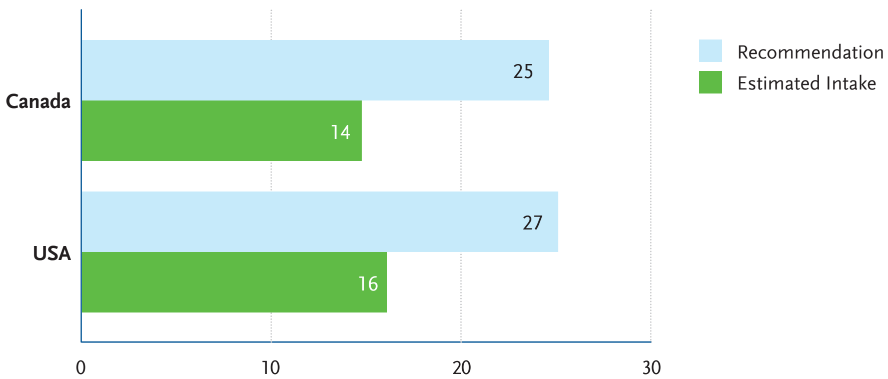
Dietary fiber remains a nutrient of concern, according to the Report on the Dietary Guidelines for Americans 2015–2020, as we all do not eat enough fiber. We only consume about half of the dietary fiber we should be eating, [24–27] (see Figure 12).

Figure 12. Fiber recommendation vs. actual intake in the U.S. and Canada

Dietary fiber in g/day (male)



Dietary fiber in g/day (female)



We need to find new ways to increase the fiber intake in our diet, since people have their limits when eating fruits and vegetables – we can only eat so much. A mix of additional fibers is needed; fibers with the scientific proof of health benefits associated with their intake. Chicory root fibers help bridge the fiber gap by enriching consumer products with fiber, still letting them taste good and providing additional metabolic benefits. Both, the sensory and physiological components of chicory root fiber create healthy fiber-rich food products that can be found in grocery stores. In addition to the fiber enrichment, inulin with its longer chain structure provides a creamy mouthfeel and helps to substitute fat in products. Short-chain inulin (oligofructose/FOS) provides a slightly sweet taste and helps to achieve sugar reduction by fiber enrichment with no compromise in taste.

In addition to getting fiber from whole foods, like fruits, vegetables and whole grains, **chicory root fiber-enriched food products are an excellent choice to help fulfill the fiber recommendation in our diet.**

Chicory root fibers, i.e. inulin, oligofructose/FOS, long-chain inulin, mixtures of shorter and longer chain inulin, **support your microbiota, your digestive health and beyond!**

Chicory root fibers

- are naturally and gently extracted from the chicory root
- feed the good bacteria inside you which is important for health and well-being
- have the strongest scientific prebiotic data with 24 human intervention studies
- are clinically proven prebiotics
- improve bowel habit and gently maintain bowel regularity
- have prebiotic benefits that go beyond gut health
- help you eat less naturally
- lower blood glucose response and insulin response
- improve calcium absorption for bone health support
- support the immune system (emerging growing science)
- are safe to eat for all age-groups and well-tolerated

As health care professionals we need to recommend consuming more fibers that show proof of health benefits. More and more research illustrates that the influence of fiber – like **chicory root fiber** – on our microbiota has benefits that go beyond digestive health. Keep your eyes open for more exciting new science on this topic!

References

1. Gibson GR, Roberfroid M (1995) Dietary modulation of the human colonic microbiota: Introducing the concept of prebiotics. J Nutr(125): 1401–1412. **http://www.ilri.org/biometrics/Publication/Abstract/Case%20study%2017%20-1.pdf**. Accessed April 13, 2016.
2. Roberfroid M, Gibson GR, Hoyles L et al. (2010) Prebiotic effects: metabolic and health benefits. Br J Nutr 104(S2): S1-S63. doi: 10.1017/S0007114510003363. **http://www.ilsi.org/Europe/Documents/2010%20BJN%20Roberfroid.pdf**. Accessed April 13, 2016.
3. Binns N (2013) Probiotics, prebiotics and the gut microbiota. ILSI Europe concise monograph series. ILSI Europe, Brussels. **http://www.ilsi.org/europe/publications/prebiotics-probiotics.pdf**. Accessed April 13, 2016.
4. Gibson GR, Scott KP, Rastall R et al. (2010) Dietary prebiotics:current status and new definition. Food Science & Technology Bulletin 7: 1–19. **https://www.researchgate.net/publication/228840917_Dietary_prebiotics_Current_status_and_new_definition**. Accessed April 13, 2016.
5. Gibson GR, Probert HM, van Loo J et al. (2004) Dietary modulation of the human colonic microbiota: Updating the concept of prebiotics. Nutr Res Rev 17(2004): 259–275. **http://journals.cambridge.org/article_S0954422404000204**. Accessed April 13, 2016.
6. Leach JD, Sobolik KD (2010) High dietary intake of prebiotic inulin-type fructans in the prehistoric Chihuahuan Desert. Br J Nutr 103(11): 1558–1561. **http://www.ncbi.nlm.nih.gov/pubmed/20416127**. Accessed April 13, 2016.
7. Sanders ME (2008) Probiotics: Definition, Sources, Selection, and Uses. Clinical Infectious Diseases 46: S58-61. **http://cid.oxfordjournals.org/content/46/Supplement_2/S58.full**. Accessed May 10, 2016.
8. Preter V de, Joossens M, Ballet V et al. (2013) Metabolic profiling of the impact of oligofructose-enriched inulin in Crohn's disease patients: a double-blinded randomized controlled trial. Clin Transl Gastroenterol 4 (Published online 10 January 2013): e30. doi: 10.1038/ctg.2012.24. **http://www.nature.com/ctg/journal/v4/n1/pdf/ctg201224a.pdf**. Accessed April 13, 2016.
9. Boets E, Deroover L, Houben E et al. (2015) Quantification of in Vivo Colonic Short Chain Fatty Acid Production from Inulin. Nutrients 7(11): 8916–8929. doi: 10.3390/nu7115440. **http://www.ncbi.nlm.nih.gov/pubmed/26516911**. Accessed May 10, 2016.
10. Frost G, Sleeth ML, Sahuri-Arisoylu M et al. (2014) The short-chain fatty acid acetate reduces appetite via a central homeostatic mechanism. Nat Commun 5: 3611. doi: 10.1038/ncomms4611. **http://www.nature.com/ncomms/2014/140429/ncomms4611/pdf/ncomms4611**.pdf. Accessed April 13, 2016.
11. Delzenne NM, Cani PD (2011) Interaction between obesity and the gut microbiota: relevance in nutrition. Annu. Rev. Nutr 31: 15–31. doi: 10.1146/annurev-nutr-072610-145146. **http://www.ncbi.nlm.nih.gov/pubmed/21568707**. Accessed April 13, 2016.
12. Gibson GR, Beatty ER, Wang X et al. (1995) Selective Stimulation of Bifidobacteria in the Human Colon by Oligofructose and Inulin. Gastroenterology 108: 975–982. **http://www.gastrojournal.org/article/0016-5085(95)90192-2/pdf**. Accessed April 13, 2016.
13. EFSA Panel on Dietetic Products, Nutrition and Allergens (2015) Scientific Opinion on the substantiation of a health claim related to "native chicory inulin" and maintenance of normal defecation by increasing stool frequency pursuant to Article 13.5 of Regulation (EC) No 1924/20061. EFSA Journal 13 (1) 3951. **http://www.efsa.europa.eu/sites/default/files/scientific_output/files/main_documents/3951.pdf**. Accessed April 13, 2016.
14. Reigstad CS, Salmonson CE, Rainey JF et al. (2015) Gut microbes promote colonic serotonin production through an effect of short-chain fatty acids on enterochromaffin cells. FASEB J. 29(4): 1395–1403. doi: 10.1096/fj.14-259598. **http://www.ncbi.nlm.nih.gov/pubmed/25550456**. Accessed May 10, 2016.
15. Collado Yurrita L, San Mauro Martin I, Ciudad-Cabanas MJ et al. (2014) Effectiveness of inulin intake on indicators of chronic constipation; a meta-analysis of controlled randomized clinical trials. Nutr Hosp 30 (2)(1699-5198 (Electronic)): 244–252. **http://www.redalyc.org/pdf/3092/309232246003.pdf**. Accessed April 13, 2016.
16. Velasquez-Manoff M (2015) Gut microbiome: the peacekeepers. Nature 518(7540): S3-11. doi: 10.1038/518S3a. **http://www.nature.com/nature/journal/v518/n7540_supp/full/518S3a.html**. Accessed April 13, 2016.
17. Cummings JH, Christie S, Cole TJ (2001) A study of fructo oligosaccharides in the prevention of travellers' diarrhoea. Aliment Pharmacol Ther 15(8): 1139–1145. **http://onlinelibrary.wiley.com/doi/10.1046/j.1365-2036.2001.01043.x/full**. Accessed April 13, 2016.
18. Ford AC, Vandvik PO (2010) Irritable bowel syndrome. Clin Evid.(Online.) 01: 410. **http://www.ncbi.nlm.nih.gov/pubmed/22296841**. Accessed May 10, 2016.
19. Bijkerk CJ, Muris J. W. M., Knottnerus J. A. et al. (2004) Systematic review: the role of different types of fibre in the treatment of irritable bowel syndrome. Aliment Pharmacol Ther 19: 245–251. **http://www.rima.org/web/medline_pdf/AlimPharmTher_245.pdf**. Accessed May 10, 2016.
20. Trinkley KE, Nahata MC (2011) Treatment of irritable bowel syndrome. J Clin Pharm.Ther 36(3): 275–282. doi: 10.1111/j.1365-2710.2010.01177.x. **http://www.ncbi.nlm.nih.gov/pubmed/21545610**. Accessed May 10, 2016.
21. Fedewa A., Rao SSC (2014) Dietary fructose intolerance, fructan intolerance and FODMAPs. Curr Gastroenterol Rep. 16(1): 370. doi: 10.1007/s11894-013-0370-0. **http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3934501/pdf/nihms551293.pdf**. Accessed May 10, 2016.
22. Hunter JO, Tuffnell Q, Lee AJ (1999) Controlled trial of oligofructose in the management of irritable bowel syndrome. J Nutr 129(S7): 1451S–1453. **http://jn.nutrition.org/content/129/7/1451S.full.pdf**. Accessed May 10, 2016.
23. Olesen M, Gudmand-Hoyer E (2000) Efficacy, safety, and tolerability of fructooligosaccharides in the treatment of irritable bowel syndrome. Am J Clin Nutr 72(6): 1570–1575. **http://ajcn.nutrition.org/content/72/6/1570.full.pdf**. Accessed May 10, 2016.
24. U.S. Department of Health and Human Services and U.S. Department of Agriculture. (2015) 2015–2020 Dietary Guidelines for Americans. 8th Edition. **http://health.gov/dietaryguidelines/2015/guidelines/**. Accessed May 10, 2016.

25. USDA Dietary Intake Data - What We Eat in America, NHANES 2011-2012. **https://www.ars.usda.gov/ARSUserFiles/80400530/pdf/1112/Table_1_NIN_GEN_11.pdf.** Accessed September 20, 2016.

26. Institute of Medicine IOM (2005) Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids (Macronutrients). doi: 10.17226/10490. **https://www.nap.edu/read/10490/chapter/1#v.** Accessed September 20, 2016.

27. Health Canada (2006) Canadian Community Health SurveyCycle 2.2, Nutrition (2004) – A Guide to Accessing and Interpreting the Data. **http://www.hc-sc.gc.ca/fn-an/alt_formats/hpfb-dgpsa/pdf/surveill/cchs-guide-escc-eng.pdf.** Accessed September 20, 2016.

28. Delzenne NM, Cani PD, Daubioul C et al. (2005) Impact of inulin and oligofructose on gastrointestinal peptides. Br J Nutr 93 Suppl 1: S157-S161. **http://journals.cambridge.org/article_S0007114505000929**. Accessed April 13, 2016.

29. Daud NM, Ismail NA, Thomas EL et al. (2014) The impact of oligofructose on stimulation of gut hormones, appetite regulation, and adiposity. Obesity 22(6): 1430–1438. doi: 10.1002/oby.20754. **http://health.gov/dietaryguidelines/2015/guidelines**/. Accessed May 10, 2016.

30. Kellow NJ, Coughlan MT, Reid CM (2014) Metabolic benefits of dietary prebiotics in human subjects: a systematic review of randomised controlled trials. Br J Nutr 111(7): 1147–1161. doi: 10.1017/S0007114513003607. **http://journals.cambridge.org/article_S0007114513003607**. Accessed April 13, 2016.

31. Cani PD, Joly E, Horsmans Y et al. (2006) Oligofructose promotes satiety in healthy human: a pilot study. Eur J Clin Nutr 60(5): 567–572. **http://www.nature.com/ejcn/journal/v60/n5/pdf/1602350a.pdf**. Accessed April 13, 2016.

32. Parnell JA, Reimer RA (2009) Weight loss during oligofructose supplementation is associated with decreased ghrelin and increased peptide YY in overweight and obese adults. Am J Clin Nutr 89(6): 1751–1759. **http://ajcn.nutrition.org/content/89/6/1751.full.pdf**. Accessed April 13, 2016.

33. Nicolucci A, Hume M, Reimer R (2015) Effect of Prebiotic Fiber-Induced Changes in Gut Microbiota on Adiposity in Obese and Overweight Children. FASEB J 29(S1). **http://www.fasebj.org/content/29/1_Supplement/276.6.abstract**. Accessed May 10, 2016.

34. International Diabetes Federation (2015) IDF Diabetes Atlas 7th edition. **http://www.diabetesatlas.org/**. Accessed May 10, 2016.

35. National Center for Chronic Disease Prevention and Health Promotion (2014) National Diabetes Statistics Report, 2014. **http://www.cdc.gov/diabetes**. Accessed May 10, 2016.

36. EFSA (2014) Scientific Opinion on the substantiation of a health claim related to non-digestible carbohydrates and a reduction of post-prandial glycaemic responses pursuant to Article 13 (5) of Regulation (EC) No. 1924/2006. EFSA Journal 2014; 12(1):3513. **http://www.efsa.europa.eu/sites/default/files/scientific_output/files/main_documents/3513.pdf**. Accessed May 10, 2016.

37. Guess ND, Dornhorst A, Oliver N et al. (2016) A Randomised Crossover Trial: The Effect of Inulin on Glucose Homeostasis in Subtypes of Prediabetes. Ann Nutr Metab 68(1): 26–34. doi: 10.1159/000441626. **http://www.ncbi.nlm.nih.gov/pubmed/26571012**. Accessed May 10, 2016.

38. Guess ND, Dornhorst A, Oliver N et al. (2015) A randomized controlled trial: the effect of inulin on weight management and ectopic fat in subjects with prediabetes. Nutr Metab (Lond) 12: 36. doi: 10.1186/s12986-015-0033-2. **http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4619305/**. Accessed May 10, 2016.

39. National Osteoporosis Foundation (2014) 54 Million Americans Affected by Osteoporosis and Low Bone Mass. **https://www.nof.org/news/54-million-americans-affected-by-osteoporosis-and-low-bone-mass/**. Accessed May 10, 2016.

40. Abrams SA, Hawthorne KM, Aliu O et al. (2007) An Inulin-Type Fructan Enhances Calcium Absorption Primarily via an Effect on Colonic Absorption in Humans. J Nutr 137: 2208–2212. **http://jn.nutrition.org/content/137/10/2208.full.pdf**. Accessed April 13, 2016.

41. Abrams SA, Griffin IJ, Hawthorne KM et al. (2005) A combination of prebiotic short- and long-chain inulin-type fructans enhances calcium absorption and bone mineralization in young adolescents. Am J Clin Nutr 82(2): 471–476. **http://ajcn.nutrition.org/content/82/2/471.full.pdf**. Accessed April 13, 2016.

42. Wopereis H, Oozeer R, Knipping K et al. (2014) The first thousand days - intestinal microbiology of early life: establishing a symbiosis. Pediatr Allergy Immunol Epub: 0. doi: 10.1111/pai.12232. **http://www.ncbi.nlm.nih.gov/pubmed/24899389**. Accessed April 13, 2016.

43. Veereman-Wauters G, Staelens S, van de Broek H et al. (2011) Physiological and bifidogenic effects of prebiotic supplements in infant formulae. J Pediatr Gastroenterol Nutr 52(6): 763–771. doi: 10.1097/MPG.0b013e3182139f39. **http://journals.lww.com/jpgn/Fulltext/2011/06000/Physiological_and_Bifidogenic_Effects_of_Prebiotic.20.aspx**. Accessed April 13, 2016.

44. Closa-Monasterolo R, Gispert-Llaurado M, Luque V et al. (2013) Safety and efficacy of inulin and oligofructose supplementation in infant formula: results from a randomized clinical trial. Clin Nutr 32(6): 918–927. doi: 10.1016/j.clnu.2013.02.009. **http://www.ncbi.nlm.nih.gov/pubmed/23498848**. Accessed April 13, 2016.

45. Coppa GV, Pierani P, Zampini L et al. (1999) Oligosaccharides in human milk during different phases of lactation. Acta Paediatr. Suppl 88(430): 89–94. **http://www.ncbi.nlm.nih.gov/pubmed/10569230**. Accessed May 10, 2016.

46. Coppa GV, Gabrielli O, Pierani P et al. (1993) Changes in carbohydrate composition in human milk over 4 months of lactation. Pediatrics 91(3): 637–641. **http://www.ncbi.nlm.nih.gov/pubmed/8441573**. Accessed May 10, 2016.

47. Ferre N, Escribano J, Castillejo G et al. (2015) The Use Of Inulin-type Fructans Improves Stool Consistency In Constipated Children. A Pilot Study: Poster presentation at the 48th Annual ESPGHAN-Congress Meeting in Amsterdam (06 - 09 May 2015). **http://journals.lww.com/jpgn/Documents/ESPGHAN%202015%20-%20Abstracts%20JPGN%20FINAL.pdf**. Accessed April 13, 2016.

48. Saavedra JM, Tschernia A (2002) Human studies with probiotics and prebiotics: clinical implications. Br J Nutr 87(S2): S241-S246. **http://journals.cambridge.org/article_S0007114502001010**. Accessed April 13, 2016.

49. Lohner S, Kullenberg D, Antes G et al. (2014) Prebiotics in healthy infants and children for prevention of acute infectious diseases: a systematic review and meta-analysis. Nutr Rev Aug 72 (8): 523–531. doi: 10.1111/nure.12117. **http://www.ncbi.nlm.nih.gov/pubmed/24903007**. Accessed April 13, 2016.