

ENTOMO FARMS
Chitin, Chitosan and Chitin-Oligosaccharide
Assessment and Health Benefits
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Role of Fiber and Oligosaccharides in Human Health

Fiber is an underappreciated component in both modern and ancestral diets, yet the gut microbiota and its vast implications for health have clearly emerged in the last 10-15 years as second generation sequencing technology illuminates the intricate relationships the intestinal microorganisms have with human health and disease. Prebiotics are defined as fiber that stimulate the growth and activity of advantageous microorganisms. From our first hours of life, prebiotic oligosaccharides in breast milk feed and nurture the gut flora of babies until weaning onto solid food. Without an immune system, babies receive immunoprotection from not only their mother's immunoglobulins but also the prebiotic oligosaccharides which have properties that reduce and eliminate pathogens such as *E. coli*, *Salmonella*, *Pseudomonas*, and *Shigella* which are associated with infection and disease.

Oligosaccharides are considered fiber ¹because they are resistant to digestion, fail to be broken in the small intestines by human digestive enzymes, and do not feed the baby or host. Instead oligosaccharides nourish and stimulate gut bacteria. Our intestinal flora help us with many functions that fortify our health that we cannot live without such as:

- breakdowning food
- producing or assimilating vitamins and nutrients
- purging opportunistic pathogens
- boosting fat burning antioxidants like conjugated linoleic acid (CLA)
- secretion of targeted antimicrobial compounds that crowd out harmful yeasts and pathogenic flora
- reversal of intestinal permeability
- balancing and improving immunity against disease and cancer

Prebiotic oligosaccharides are found abundantly in nature and food such as lentils, legumes, green leafy vegetables, agave cacti, and non-starchy vegetables such as sunchoke, onions, and yacon roots. They are vital constituents to the human diet and provide not only protection against pathogens and metabolism benefits. Prebiotic oligosaccharides have been shown in both human and animal studies to be associated with significant reduction in body

¹ Knol, Jan et al. "Increase of faecal bifidobacteria due to dietary oligosaccharides induces a reduction of clinically relevant pathogen germs in the faeces of formula - fed preterm infants." *Acta Paediatrica* 94.s449 (2005): 31-33.

fat, decreased inflammation, improvements in metabolic syndrome, and decreased fatty liver/nonalcoholic steatohepatitis. ²

Table 5 Studies conducted on humans showing effects of prebiotics on metabolic disorders

Studied subject	Prebiotic	Duration of treatment	Effects	Ref.
Healthy men and women	OFS	2 wk	↓Food and energy intake, hunger ↑satiety	[132]
Healthy humans	GOS	12 wk	Significant ↑ <i>Bifidobacterium</i>	[133]
Obese women	Inulin-type fructans	3 mo	↑ <i>Bifidobacterium</i> and <i>Faecalibacterium prausnitzii</i> ↓Circulating LPS, <i>Bacteroides</i> , <i>Propionibacterium</i>	[134]
Obese-dyslipidemic women	Yacon syrup (containing OFS)	120 d	↓Body weight, BMI, waist circumference, serum LDL cholesterol levels	[135]
Overweight and obese adults	OFS	12 wk	↓Body weight, ghrelin, calories intake, serum glucose, insulin ↑peptide YY	[136]

OFS: Oligofructose; GOS; Galactooligosaccharides; LPS: Lipopolysaccharides; BMI: Body mass index; LDL: Low-density lipoprotein.

Benefits of Prebiotic Oligosaccharides in Human Subjects (Festi et al WJG 2014)

Chitin and Its Health Benefits

Through evolutionary time for millennia, humans and their hominid ancestors consumed insects, grub, larvae and other faunivory. These foods are rich in soluble and insoluble fiber, brain-enriching omega-3 fatty acids, vital minerals, vitamin B12 and other B vitamins -- nutrients which are only otherwise found in seafood and meat.³⁴ Chitin is a special insoluble fiber found in fungi, mushrooms, yeast cell walls, and shells of crustaceans and insects. The polysaccharide structure is analogous to indigestible cellulose in plants, in fact, after cellulose, chitin is the second most abundant natural carbohydrate on earth. Chitin is a long chain polymer of N-acetyl-glucosamine that selectively feeds vital populations in the human gut microbiota which are responsible for maintaining proper functioning of the gut, intestinal mucosa integrity and barrier control, immunoprotection and energy efficient metabolism.

² Festi, Davide et al. "Gut microbiota and metabolic syndrome." *World journal of gastroenterology: WJG* 20.43 (2014): 16079.

³ "The contribution of insects to food security, livelihoods and ..." 2013. 14 Apr. 2015

<<http://www.fao.org/docrep/018/i3264e/i3264e00.pdf>>

⁴ "Edible insects." 2013. 14 Apr. 2015 <<http://www.fao.org/docrep/018/i3253e/i3253e00.htm>>

Chitin may play a role in preventing or reversing modern disorders such as diabetes and obesity.⁵⁶⁷

Amendment of soil with chitin (chitinous matter from shrimp) was shown to reduce soil pathogens and improve soil quality and diversity.⁸ Activity of chitin may involve enhancement of colonization resistance against pathogens by the native, indigenous flora.⁹



“Chitosan -- Technologically Important Biomaterial”¹⁰

Benefits of Chitosan and Chitin-Oligosaccharides (COS)

Both deacetylated chitin, known as chitosan, and chitin are used as a nutritional supplements around the world for weight loss and cholesterol management. The chitosan content of cricket flour or cooked cricket flour products does not appear to be assessed yet. Chitosan derived from mushrooms were associated with increased resistance to body fat increases, improved inflammatory markers, and restoration of beneficial gut flora in diet-induced obese mice on high-fat diets.¹¹ Some of the benefits of chitosan may be related to its antimicrobial and antifungal properties against common gut pathogens that overgrows after antibiotic use, *Candida albicans* (yeast) and bacterial pathogens selected after

⁵ Geurts, Lucie et al. "Gut microbiota controls adipose tissue expansion, gut barrier and glucose metabolism: novel insights into molecular targets and interventions using prebiotics." *Beneficial microbes* 5.1 (2014): 3-17.

⁶ Delzenne, Nathalie M, and Patrice D Cani. "Nutritional modulation of gut microbiota in the context of obesity and insulin resistance: Potential interest of prebiotics." *International Dairy Journal* 20.4 (2010): 277-280.

⁷ Neyrinck, Audrey M et al. "Dietary modulation of clostridial cluster XIVa gut bacteria (*Roseburia* spp.) by chitin–glucan fiber improves host metabolic alterations induced by high-fat diet in mice." *The Journal of nutritional biochemistry* 23.1 (2012): 51-59.

⁸ Cretoiu, Mariana Silvia et al. "Chitin amendment increases soil suppressiveness toward plant pathogens and modulates the actinobacterial and oxalobacteraceal communities in an experimental agricultural field." *Applied and environmental microbiology* 79.17 (2013): 5291-5301.

⁹ Burketová, Lenka et al. "Bio-based resistance inducers for sustainable plant protection against pathogens." *Biotechnology Advances* (2015).

¹⁰ Raafat, Dina, and Hans - Georg Sahl. "Chitosan and its antimicrobial potential—a critical literature survey." *Microbial Biotechnology* 2.2 (2009): 186-201.

¹¹ Neyrinck, Audrey M et al. "Dietary supplementation with chitosan derived from mushrooms changes adipocytokine profile in diet-induced obese mice, a phenomenon linked to its lipid-lowering action." *International immunopharmacology* 9.6 (2009): 767-773.

broad-spectrum antibiotics.^{12,13} In vitro studies show that chitosan inhibits planktonic growth of *Candida*.¹⁴ Researchers at Universidade Católica Portuguesa studying chitosan report, "In general, *Candida* is an opportunistic pathogen, causing infections in immunocompromised people and, in some cases, when the natural microbiota is altered. Chitosan, a natural derivative of chitin, is a polysaccharide that has been proven to possess a broad spectrum of antimicrobial activity that encompasses action against fungi, yeast and bacteria."¹⁵

Via mammalian digestion and gut flora degradation, chitin is broken down to chitin-oligosaccharides. Like prebiotic oligosaccharides from dietary sources and human breastmilk, chitin-oligosaccharides are demonstrated to possess a wide array of similar health benefits.¹⁶

Chitin-oligosaccharides may also be sourced from enzyme treated shrimp exoskeletons and edible mushrooms (chitin-glucan, from fungal cell walls). In hybrid tilapia fish farming, chitinase (ChiB565)-hydrolyzed shrimp shell chitin (chitin-oligosaccharide, COS) was demonstrated to improve fish health compared with commercially prepared chitosan-oligosaccharides.¹⁷ Dose related benefits (Control v. 0.8% v. 1.6% v. 2.4%) observed included less mortality when challenged with a pathogen *A. hydrophila*, improved intestinal health, changed autochthonous gut bacteria, and improve resistance to infection.

¹² Raafat, Dina et al. "Insights into the mode of action of chitosan as an antibacterial compound." *Applied and environmental microbiology* 74.12 (2008): 3764-3773.

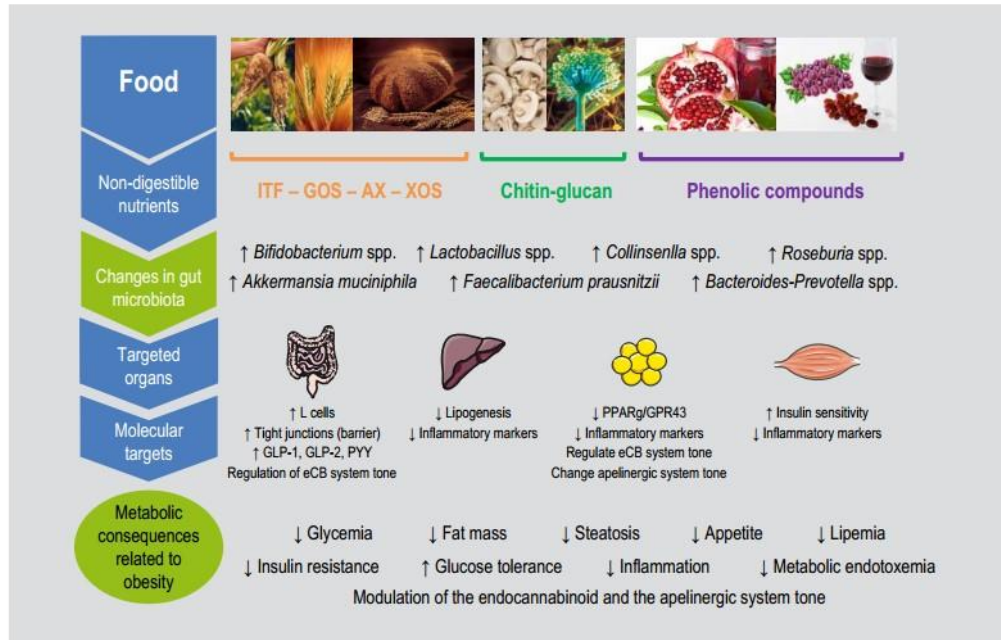
¹³ Raafat, Dina et al. "Chitosan as an antibacterial compound: Insights into its mode of action." *Applied and Environmental Microbiology* (2008).

¹⁴ Costa, Eduardo et al. "Antimicrobial and Antibiofilm Activity of Chitosan on the Oral Pathogen *Candida albicans*." *Pathogens* 3.4 (2014): 908-919.

¹⁵ Costa, Eduardo et al. "Antimicrobial and Antibiofilm Activity of Chitosan on the Oral Pathogen *Candida albicans*." *Pathogens* 3.4 (2014): 908-919.

¹⁶ Azuma, Kazuo et al. "Anticancer and Anti-Inflammatory Properties of Chitin and Chitosan Oligosaccharides." *Journal of functional biomaterials* 6.1 (2015): 33-49.

¹⁷ Qin, Chubin et al. "Effects of chito-oligosaccharides supplementation on growth performance, intestinal cytokine expression, autochthonous gut bacteria and disease resistance in hybrid tilapia *Oreochromis niloticus*♀ × *Oreochromis aureus*♂." *Fish & shellfish immunology* 40.1 (2014): 267-274.



Chitin-Glucan From Fungal Sources

And Its Beneficial Effects on the Gut Microbiota and Inflammation

<http://www.uclouvain.be/cps/ucl/doc/ir-ldri/images/geurts2013.pdf> **Modern Diseases Appears to Involve Amyloid Plaques and Chitin-Oligosaccharides Dissolve Amyloid Plaques In Vitro**

In the modern age of readily available sweets, soda and simplified, low-fiber carbohydrates, our bodies can only handle certain thresholds before becoming reservoirs of metabolic damage. In animal models, amyloid plaques develop in the pancreas and brain as a consequence of sucrose ingestion and elevated blood sugars and insulin.¹⁸ Metabolic syndrome and Diabetes Type 3 (aka Alzheimer's Disease) are the resultant disorders, in addition to cancer, obesity and degenerative joints.

Prebiotic oligosaccharides from animal, insect and plant sources may be the ancestral keys linking our high fiber past and practice of faunivory to reducing inflammation and even reversing modern health disorders. New animal studies show how chitosan oligosaccharides may reduce inflammation and rat primary hippocampal neurons from β -amyloid neurotoxicity.¹⁹ In cognitive deficits associated with Alzheimer's, in in vitro models, chitin-oligosaccharides suppress the level of protein expression and acetylcholinesterase activity demonstrating they may have value and merit similar to the

¹⁸ Westermark, Per, Arne Andersson, and Gunilla T Westermark. "Islet amyloid polypeptide, islet amyloid, and diabetes mellitus." *Physiological reviews* 91.3 (2011): 795-826.

¹⁹ Dai, Xueling et al. "Chitosan oligosaccharides protect rat primary hippocampal neurons from oligomeric β -amyloid 1-42-induced neurotoxicity." *Neuroscience letters* 554 (2013): 64-69.

mechanism of action of pharmaceuticals used for Alzheimer's to increase neurotransmitters.²⁰

Insect Faunivory Provides High Fiber and Chitin

From the FAO, 2103 'Nutritional Values of Insects for Human Consumption':

6.1.8 Fibre content²¹

Insects contain significant amounts of fibre, as measured by crude fibre, acid detergent fibre and neutral detergent fibre. The most common form of fibre in insects is chitin, an insoluble fibre derived from the exoskeleton. A significant amount of data is available on the fibre content of insects, but it has been produced by various methods and is not easily comparable (H. Klunder, personal communication, 2012). Finke (2007) estimated the chitin content of insect species raised commercially as food for insectivores, and found it to range from 2.7 mg to 49.8 mg per kg (fresh) and from 11.6 mg to 137.2 mg per kg (dry matter) . Chitin, the main component of the exoskeleton of an insect, is a long-chain polymer of N-acetyl glucosamine – a derivative of glucose. Chitin is much like the polysaccharide cellulose found in plants, which is largely believed to be indigestible by humans, although chitinase has been found in human gastric juices (Paoletti et al., 2007). Chitin has also been associated with defence against parasitic infections and some allergic conditions. The above study, carried out among Italians, showed an absence of chitinase activity in 20 percent of cases. Chitinase activity is more prevalent in tropical countries where insects are regularly consumed; there may be a lower rate of chitinase activity in Western countries due to the absence of chitin in the diet. Some argue that chitin acts like a dietetic fibre (Muzzarelli et al., 2001), and this could imply a high-fibre content in edible insects, especially species with hard exoskeletons (Bukkens, 2005).

Crickets and Their Products are 'High Fiber Foods'

²⁰ Lee, Sang-Hoon et al. "Chitooligosaccharides suppress the level of protein expression and acetylcholinesterase activity induced by A β 25–35 in PC12 cells." *Bioorganic & medicinal chemistry letters* 19.3 (2009): 860-862.

²¹ "Nutritional values of insects for human consumption - Food ..." 2013. 14 Apr. 2015
<<http://www.fao.org/docrep/018/i3253e/i3253e06.pdf>>

The average total dietary intake of fiber in the Western civilization is approximately 16 grams fiber daily. Total dietary fiber in cricket flour is estimated to be between 6 to 8 grams per ²² 100g amount.²³²⁴ If an individual consumes only 100 gram portion of cricket flour, they may increase their average total fiber by 50%.

The chitin content of insects may be variable and estimated in the range of 12 to 128 mg per kilogram of dry mass. Chitin is broken down to chitin oligosaccharides through digestion (gastric enzyme chitinase and/or gut flora related chitinase). Chitin and soluble chitin oligosaccharides (COS) do not appear to have been quantified in processed cricket flour or cricket flour cooked food products.