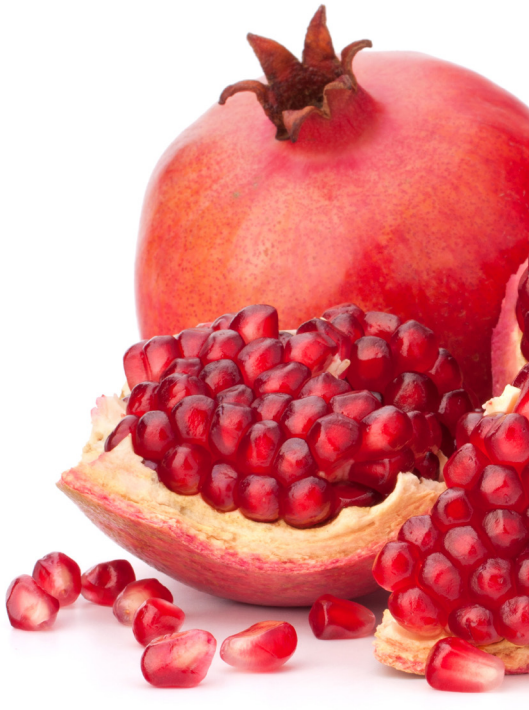
Education Article

Digestive Enzymes: The Key to Optimum Health

Digestion is essential for good health. Unlocking nutrients from foods is a complex process. In order to break down food we rely on optimal levels and function of a special set of proteins called digestive enzymes. These proteins are found in the saliva and also in the small intestines. Without the combined actions of our digestive enzymes we would simply be unable to absorb many nutrients that we need to maintain good health. This is why reduced levels of digestive enzymes can be linked to a wide-range of symptoms within the gut and beyond.

Digestive enzymes, along with stomach acid, play a crucial role in the initial stages of digestion, i.e. the breaking down of the food that we eat. The main classes of human digestive enzymes include proteases, lipases and carbohydrases, which respectively break down the macronutrients protein, fats and carbohydrates. If we do not efficiently digest these foods then vital nutrients such as essential fats, vitamins, minerals and phytonutrients cannot be absorbed. What is more, undigested or partially digested food passes through into the large intestines and is fermented by the resident colonic bacteria, causing unpleasant symptoms such as bloating and flatulence and contributing to a toxic bowel. Naturopaths believe toxicity within the bowel is the root of all disease. We do not make digestive enzymes for every type of food that we eat, such as gluten and phytic acid found in some grains and cereals and lactose, a sugar found in milk. This means our bodies may find it difficult to digest these types of foods. It should be no surprise that intolerances and allergies to these indigestible types of foods are common and contribute to many different symptoms and conditions.

Plants and special microbes contain a wider spectrum of enzymes that support digestion of many different foods including gluten, phytic acid and lactose. This is why eating foods that are rich in natural digestive enzymes and using plant digestive enzyme supplements may be extremely beneficial for many conditions by helping to maintain digestion perfection.

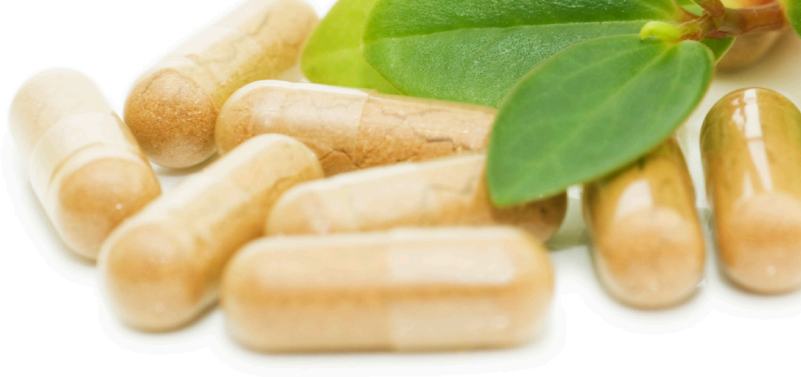


What are digestive enzymes?

Enzymes are naturally occurring proteins that function as “catalysts” during the many different biological reactions that take place within the cells of our body. Catalysts help speed up reactions and, in the case of enzymes, they enable metabolic and physiological reactions to quickly and efficiently take place reducing the amount of energy needed and speeding up the reaction. Enzymatic activity takes place every second of every day throughout our bodies and makes life possible. In fact vital biological reactions such as digestion of food or production of energy would take millions, maybe even billions, of times longer without enzymes!

In humans, enzymes can be catagorised as either digestive or metabolic in function. The latter larger group of enzymes catalyse many different biochemical reactions that take place in the body’s cells and tissues underlying essential processes like energy production, synthesis and repair of cell structures and replication of genetic material. On the other hand, the group of naturally occurring digestive enzymes, present in the saliva, stomach and intestines, help breakdown macronutrients such as protein, fats and carbohydrates found in our diet.

There are also food enzymes found in raw plant material like fresh fruit and vegetables that support digestion of the very material that is contained within plants, including phytates (or phytic acid) and cellulose (i.e. insoluble plant fibre). We do not make these types of digestive enzymes so they can only be obtained from plant sources. This is very useful to us as when we ingest plant material we are also ingesting their specific digestive enzymes, which help us to break down plant material such as phytic acids and cellulose fibres that we would otherwise be unable to digest. This enhances the bioavailability of valuable nutrients, like essential minerals, that might otherwise have been locked into the food by plant compounds such as phytic acid or cellulose fibres. Of course this depends on the plant enzymes not being destroyed by food processing. The function and benefits of plant enzymes will be discussed later in this newsletter.



What is digestion?

Digestion is the process of breaking down and absorbing food and is helped by juices containing digestive enzymes secreted from the salivary glands and pancreas as well as acid produced in the stomach (Figure 1). As we eat, the process of chewing food stimulates saliva production and digestive enzymes can get to work on carbohydrates (Table 1). As we swallow the muscular action of the oesophagus moves food down into our stomach where it mixes with stomach acid to help break down food. The stomach is essentially a bag made of muscle so the food (or chyme as it's now called) is churned and mixed by muscular contractions further helping digestion to take place.

A complex control network of hormones and pH levels signals for the chyme to be slowly released into the duodenum portion of the small intestines (Figure 1). As this is happening the pancreas releases its juices, rich in digestive enzymes (Table 2), into the common bile duct where they mix with bile synthesised in the liver and stored in the gall bladder. A special muscle called the Sphincter of Oddi controls the release of pancreatic juices and bile into the duodenum so the next and final stages of breaking food down through the action of a variety of different digestive enzymes can take place. Nutrients are then absorbed across the gut barrier in the jejunum and ileum parts of the small intestines. The gut barrier in this part of the digestive tract is made up of lots of finger like projections called "villi" that extend into the gut lumen and greatly increase the surface area allowing more nutrients to be absorbed into the hepatic portal vein blood stream and transported to the liver and the rest of the body. This is true for proteins and carbohydrates in the food that we eat.

However the majority of fats and oils in our diets are handled a little differently. Many types of fats require bile to help emulsify them ready for the fat digesting enzymes (i.e. lipases) to work. The digested fats are then packaged up and are transported across the villi into the lacteal system, which drains into the lymphatic system before passing onto the liver via the blood. This is a very energy dependent process, which is why many people struggle with digesting large quantities of fats in the diet.

Not all of the contents of the small intestines are absorbed so the remainder passes on through the different portions of the colon, where the majority of water is absorbed. If all the stages and organs function efficiently and are in good health then digestion perfection is achieved.[1] Of course, there are many stages when this complex process does not work so extra support is required.[2]

How do digestive enzymes work?

Digestive enzymes catalyse, or trigger, the breaking down of food in the mouth and gut so nutrients are released and can be absorbed across the intestinal barrier into the blood stream. Therefore one of the main functions of digestive enzymes is to increase the bioavailability of nutrients.[1]

Most digestive enzymes are considered hydrolyases. That is they break the natural chemical bonds in foods by the addition of water ("hydro" means water and "lysis" means separation). They do this by binding foods (i.e. the substrate) to their active site deep within their protein structure so the reaction can occur, breaking down the food material. One can think of an enzyme's active site as being like a pocket, only a pocket that is specific for just one type of substrate. This means digestive enzymes have a high degree of specification for the foods they act upon. We shall look at the different types of digestive enzymes and the specific foods they break down in later sections of this newsletter. Enzymes are also able to carry out more than one reaction. When the digested food is released from the enzyme pocket after the reaction is complete the process starts again.

However, digestion is not quite as simple as food binding to the enzyme pocket, being broken down by the addition of water then the digested food released ready for absorption. Enzyme reactions do not just happen as soon as the enzyme and substrate comes together. Enzymatic reactions are highly dependent on optimal "test tube" conditions within the digestive tract including temperature and pH, which are altered in people with poor health, illness and chronic disease. This means optimal digestion is based not just on digestive enzyme levels but also condition of the digestive tract. One just needs to think of coeliac disease where the villi finger-like structures in the small intestines are destroyed by allergic responses to gluten.[3] Small intestines denuded of villi means very poor absorption of most nutrients.

Enzyme structure is also key to their ability to lock in the substrate ready for a reaction to take place. Temperature can greatly affect enzyme structure and cooking and processing plant foods destroys the inherent enzyme activity. One only needs to think of the difference between raw and processed milk, which has been exposed to high pasteurisation temperatures and procedures. You are probably beginning to see quite how complex enzyme action is!

Human digestive enzymes

Human digestive enzymes are mainly synthesised in the salivary glands (Figure 1 and Table 1) and in the pancreas (Figure 1 and Table 2).[4] As we've discussed, enzymes are made up of amino acids found in proteins so a ready supply of these building blocks is required to ensure there are optimal levels of digestive enzymes at all times.

Digestive enzymes are mixed in the saliva and pancreatic juices and are released into the mouth and small intestines, respectively, to support digestion of proteins, fats and carbohydrates. Their synthesis and release occurs via carefully orchestrated and tightly controlled hormone systems that are activated not just when food hits our taste buds but also by the sight, smell and sound of the food. This is why it's important to consider not just what you eat but also how you eat to help support optimal digestion.

The pancreas plays a central role in the production of the majority of our digestive enzymes. It is a very important organ, as the endocrine Islet of Langerhans cells are responsible for the production of hormones such as insulin and glucagon, whilst the exocrine cells produce digestive enzymes and bicarbonate ions, which are released into the small intestine via the bile duct.[1] This means within the biliary tract, the digestive enzymes and bicarbonate ions released in the pancreatic juices mix with bile. The bile and bicarbonate ions help regulate the pH within the small intestines to optimise conditions for digestive enzyme function (Figure 1). Bile is also essential for fat digestion.

Table 1: Classes of human salivary digestive enzymes

Saliva consists of alkaline juice of pH 7.5 with water, salts, digestive enzymes and other glycoproteins, like lactoferrin to support iron absorption. Salivary enzymes start digestion in the mouth of certain food groups such as carbohydrates. Pancreatic digestive enzymes released into the small intestines do the majority of digestive work. Salivary digestive enzymes include:

Carbohydrases - break down dietary carbohydrates

- **Amylase** - breaks down starch, glycogen and other carbohydrate polysaccharides into disaccharides
- **Maltase** - breaks down maltose Lipases - break down a minority of dietary fats
- **Lipase** - hydrolyses a very small percentage of triglycerides into fatty acids and monoglycerides

Table 2: Classes of human pancreatic digestive enzymes

Digestive enzymes are divided according to the groups of foods they breakdown. These include:

Lipases - break down majority of dietary fats at optimum pH 8.0

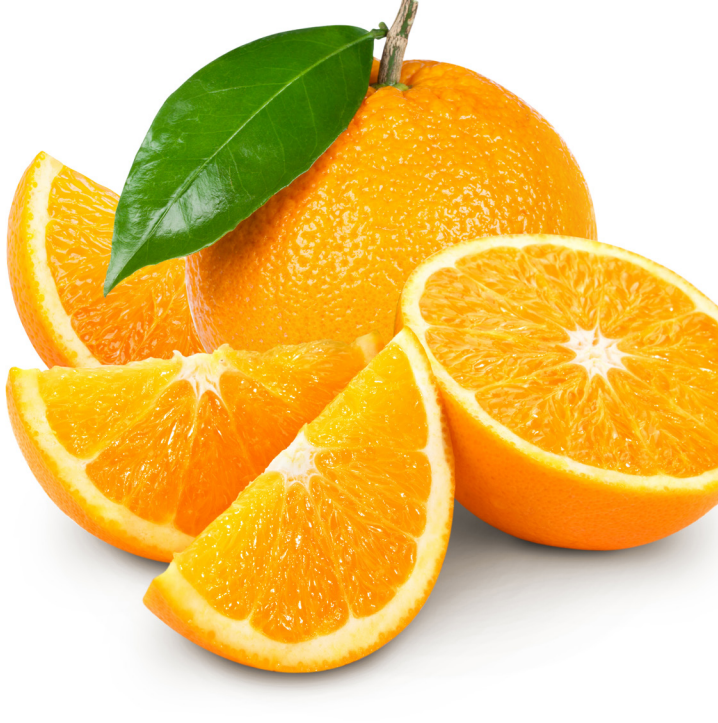
- **Lipase** – hydrolyses triglycerides into fatty acids and monoglycerides
- **Phospholipase** – splits the fatty acids of phospholipids
- **Esterase** – hydrolyses cholesterol esters

Proteases - break down proteins at optimum pH 7.9-9.7

- **Trypsin and chymotrypsin –** breaks down protein polypeptides in dipeptides
- **Carboxypolypeptidase –** splits peptides into individual amino acids

Carbohydrases - break down carbohydrates at optimum pH 6.7-7.2

- **Amylase** – breaks down starch, glycogen and other carbohydrates polysaccharides into disaccharides



Classes of digestive enzymes

Lipases

Lipase breaks down lipids (fats and oils) into free fatty acids in the stomach and duodenum, ready for absorption across the gut barrier into the lacteal system. Pancreatic lipase is by far the most active of all the lipase enzymes though the pancreas also secretes phospholipases to break down phospholipids such as phosphatidyl choline. Digestion of many fats is a lengthy process requiring the presence of bile to help emulsify the fat so that it can bind to lipase enzymes to be broken down. Consequently fat digestion is heavily dependent on optimal liver, gallbladder and pancreatic health. Phospholipid types of fats do not require emulsification by bile and are absorbed directly into the blood stream rather than the lacteal system. This means phospholipids are more easily digested and absorbed across the gut barrier. Interestingly, Krill oil omega 3 essential fatty acids are in phospholipid form so have better bioavailability compared to fish oil and flaxseed oil omega 3 essential fatty acids, which are in triglyceride form.[5]

Benefits of lipases

Pancreatic lipase is the most important digestive enzyme, as it is not adequately produced outside of the pancreas. Poor digestion of triglycerides leads to excessive fat in the stools (steatorrhea) and impaired absorption of fat-soluble nutrients such as essential fatty acids and vitamins A, D, E, K.[6] In fact human studies have shown that supplementing with a microbialderived lipase reduced fat in stools and improved fat digestion in patients with cystic fibrosis.[7]

Proteases

This class of enzymes breaks down proteins in foods such as meats, dairy, eggs and plants into smaller fragments known as peptides. Dietary protein digestion begins in the stomach with the acid stable protease pepsin, which is stable in acid, breaking down the large protein polypeptide chains. Proteases in the pancreatic juices and intestine then break the peptide bonds down further so that only small peptide units and individual amino acids remain ready for absorption and utilisation in the cells. Proteases that breakdown amino acids from the ends of the polypeptide protein chains are called exopeptidases, whereas those that cleave internal bonds within the peptide chain are termed endopeptidases. Proteases can function across as wide pH range as demonstrated by their action in the stomach and small intestines.

Benefits of proteases

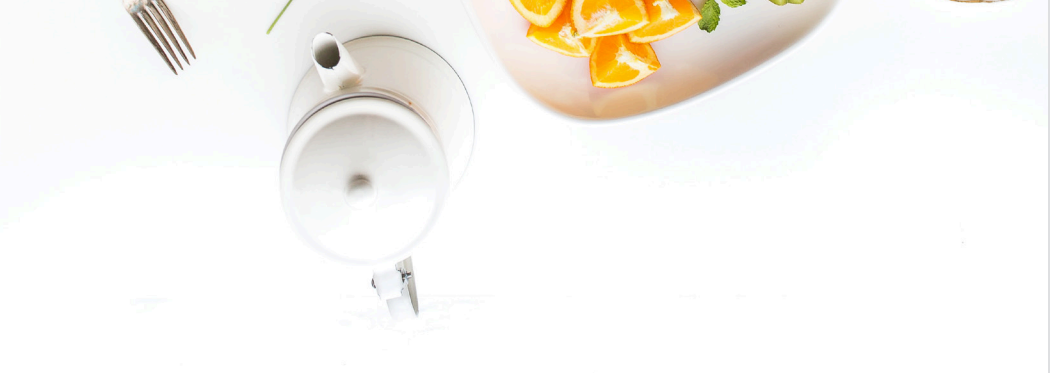
Proteolytic enzymes (i.e. proteases) taken with a meal can help in the breakdown of dietary protein. This enhances not only protein digestion but also may increase digestion of fibrous plant material by degrading proteins in plant cells walls, allowing for increased exposure to fibrolytic enzymes found in plants and some types of microbe.[8] Proteases also help break down protein chains in foods that may trigger allergies in sensitive individuals.[9] To support digestion, protease supplements should be taken with food. When taken between meals then proteases can be absorbed through the intestinal barrier and are capable of modulating a number of biochemical reactions throughout the body including reducing inflammatory.[10,11]

Carbohydrases

These enzymes facilitate the breakdown of dietary carbohydrates such as starches, fibres and sugar. Carbohydrate digestion begins in the mouth with salivary amylase breaking down starch. The process slows down in the acidic conditions of the stomach but resumes again in the optimal pH levels of the duodenum where carbohydrases in the pancreatic juice break down the smaller chains of sugars (i.e. poly and disaccharide chains) into their corresponding sugar units (i.e. monosaccharides) such as glucose. Many plant fibres are indigestible, as we do not posses specific digestive enzymes to break them down. There are many other different types of plant and microbe digestive enzymes that we will discuss later on in this newsletter.

Benefits of carbohydrases

These enzymes facilitate the breakdown of Digestion of carbohydrates is crucial for us to absorb sugars and starches. Certain digested carbohydrates also serve as sources of food for the growth of beneficial gut bacteria, which act to support our health in many ways including production of certain vitamins, regulation of immune system activity and further digestion and absorption of nutrients. Incomplete digestion of sugars and starches from the diet can lead to fermentation by gut bacteria. This in turn may contribute to many symptoms including Irritable Bowel Syndrome (IBS), diarrhoea, bloating and flatulence so optimal levels of carbohydrases found in saliva and pancreatic juices are essential to health.[12] However we do not synthesise digestive enzymes for many of our dietary carbohydrates, which is why plant, and microbial carbohydrases are so important.



Digestive enzyme insufficiency

Plenty of evidence has been presented explaining the importance of digestive enzymes to our health, namely in enhancing the bioavailability of nutrients in the foods that we eat. However, there are many reasons why we do not make enough of our own digestive enzymes. Poor enzyme production can lead to problems of nutrient insufficiency and even deficiency resulting in a whole host of health problems. We will now explore the impact that reduced levels of digestive enzymes have on our health.

Causes of digestive enzyme deficiency

It stands to reason that poor exocrine pancreatic function will result in reduced output of digestive enzymes. The causes of Exocrine Pancreatic Insufficiency (EPI)[6] are very diverse ranging from:

- Poor function of the Sphincter of Oddi that controls release of bile and pancreatic juices from the bile duct into the small intestines Problems with the endocrine part of the pancreas such as insulin dysregulation from diet high in refined carbohydrates and diabetes
- Gall stones that block the bile duct and reduce/halt the flow of pancreatic juices
- Alcohol abuse
- Micronutrient deficiency
- Diets high in refined carbohydrates causing hypoglycemia, insulin resistance and diabetes (see above)
- High calorie intake
- Too little or too much exercise

Other lifestyle factors that greatly impact on digestive enzyme output include:

- Stress
- Smoking
- Ageing leads to a decline in pancreatic and digestive function.

Stress is the most common culprit for our bodies being unable to produce sufficient digestive enzymes! Our bodies are not equipped to digest while we are stressed. The stress “flight or fight” response means blood is diverted away from the digestive tract and to the muscles and brain. This is a clever system designed to help us to escape from the sabre tooth tiger many millennia ago, but is now a mechanism that is all too often stimulated in our daily lives from stressful jobs to family life. This means that digestive enzymes will only be synthesised and released when our body finally has a moment to relax. If we readily eat while we are stressed, food will remain partially digested and ferment in the gut. The image that should come to mind is your rubbish bin if it has not been collected after a couple of weeks – old food building up and starting to rot! Making changes to a stressful lifestyle is key to supporting digestive enzyme production and optimal digestion.

One also has to consider a deficiency in the starting material for making enzymes in the first place. If there are not enough of the right amino acids available and micronutrient cofactors to synthesise the digestive enzymes in the pancreas and salivary glands then this will lead to reduced nutrient bioavailability, including the nutrients such as amino acids required for enzyme synthesis. You can see how this presents a rather vicious circle where digestive enzyme deficiency reduces amino acids and micronutrients resulting in further enzyme deficiencies. A diet containing a variety of protein sources including vegetable proteins found in legumes and beans helps to support the synthesis of natural digestive enzymes.

Symptoms of digestive enzyme insufficiency

There are many symptoms relating to digestive enzyme insufficiency. Let’s face it if you are not absorbing all the essential nutrients from your diet then there could be no end to the potential impact on your health!

Symptoms of digestive enzyme insufficiency[13] are going to become first apparent in the gut. Many people experience the following symptoms either acutely or for long periods of time:

- Bloating
- Flatulence
- Abdominal pain or discomfort
- Irritable bowel type symptoms
- Diarrhoea
- Constipation
- Dysbiosis of gut flora such as Candida Undigested food in the stools
- Stools that float (steatorrhea)
- Feeling full after only a few mouthfuls Food allergies and intolerances

The wider impact of digestive enzyme deficiency on health includes[13]:

- Obesity
- Allergies and poor immune function Depression and anxiety
- Premenstrual Syndrome
- Fatigue
- Autoimmune conditions such as coeliac disease
- Ulcerative colitis and Crohn’s disease

The need for digestive enzyme supplementation

It was in the 1940s that the use of food enzymes in clinical nutrition was first proposed.[14] Researchers concluded that wild animals eat exclusively raw food, as did primitive humans, before the discovery of fire. The proposal was that raw food contains enzymes vital to the digestive process sparing the body from having to produce all the enzymes necessary to digest a meal.

Early experiments set out to validate the hypothesis of the presence of digestive enzymes present in raw food.[15] For example, raw oats contain natural levels of amylase, a starchdigesting enzyme. Processing raw oats and storing them at the right temperature and pH levels required for optimal enzyme activity showed that with time, the levels of starch in the oat mixture decreased as monosaccharide sugar levels increased (i.e. the breakdown product of starch). However, sterilised oats (i.e. oats that had been cooked to deactivate enzymes), showed no significant reduction in starch levels. These studies demonstrate that certain foods exhibit autolytic activity, i.e. they contain natural levels of digestive enzymes.[16] What these studies also tell us is that heating and processing foods destroys the natural digestive enzymes. This means consuming a certain amount of raw and lightly steamed plant derived foods may help support digestion. Of course, this does not suit everyone so a plant-derived digestive enzyme supplement can be used.

There are also animal derived digestive enzyme supplements available but as we shall explore in a later section of this newsletter, these are not suitable for vegetarians and vegans and have a limited enzyme activity compared to plant and microbial digestive enzymes.

Importance of plant digestive enzymes

Our bodies come into contact with a huge variety of different foods on a daily basis. However we simply do not make digestive enzymes for many of those foods, such as gluten proteins, lactose sugar found in dairy produce, phytic acids found in many plants and also raffinose, a sugar found in foods such a beans, legumes and cruciferous vegetables like broccoli and brussel sprouts that causes flatulence. If we are not digesting food efficiently then we will not be deriving the benefits of all the nutrients contained within. This may lead to problems of nutrient deficiencies, as well as poor digestion leading to uncomfortable gut symptoms such as bloating, flatulence, and diarrhoea and/or constipation or even intolerances and food allergies. For this reason addressing the food that we eat, how we prepare it to retain natural digestive enzymes as well as plant-based enzyme supplements may play a great role in supporting health.[13]

Digestive enzymes derived from plants and certain fungal microbes have lipase, protease and carbohydrase activities, like human digestive enzymes, but for a much wider variety of foods. They also synthesise enzymes that help to break down plant fibres (fibrolytic enzymes), which we do not make ourselves. Table 3 outlines some examples of different digestive enzymes that compliment human digestion.

Table 3: Plant and microbial digestive enzyme function

Digestive enzyme class	Type	Function
Lipases	**Lipase** found in humans, plants and certain microbes	Essential for digestion of fats (e.g. triglycerides and phospholipids) in conjunction with the emulsification effects of bile salts (lecithin) that are released from the gallbladder. Lipase from pancreatic juices and bile from the gallbladder mix in the bile duct and are secreted into the duodenum. Lipase deficiency can lead to steatorrhea and many fat handling problems in the body.[6]
Proteases	**Gluten proteases** found in certain microbes	Digest highly resistant proline-rich peptides in gliadin fraction of gluten[17] and casein that can lead to activation of the immune system in the gut resulting in autoimmune damage to intestinal tissue as seen in conditions like coeliac disease.[18,19,20] In addition, gluten and casein-derived proline-rich peptides may exert opioid-like activity in the central nervous system causing sedation (i.e. post-meal drowsiness) and food addictions. Think of feeling sleepy after a carbohydrate heavy meal or even feeling addicted to bread! Further along this neurological scale gluten and casein are believed to trigger neurological symptoms encountered in children with autism spectrum disorders.[21,22] Gluten is most prevalent in wheat and processed bread products. Casein makes up 80-90% of cow's milk proteins versus 0.2% goat's milk.
	Alkali proteases found in certain microbes	Digest proteins within pH range of 4-11. Optimal activity is around pH 6, which is found in the small intestines.
	Acid proteases found in certain microbes	Digest proteins within pH range of 2-6, which is the range found in the stomach and small intestines. Optimal activity is around pH 4.5.
	Bromelain found in pineapples	When taken with food bromelain contains protease enzymes to help digest proteins to small peptides and individual amino acids.[23]
Carbohydrases	**Amylase** found in humans and certain microbes	Starch and glycogen specific enzymes that break down polysaccharides into disaccharides. Also works in conjunction with gluten-specific proteases to break down the carbohydrate portion of gliadin found in gluten that, along with the proline peptides, causes autoimmune damage and symptoms found in conditions like coeliac disease and gluten intolerance.[24,25] It is important to supplement with both amylase and gluten-digesting proteases for full benefits.
	Amyloglucosidase found in plants and certain microbes	Breaks down amylase disaccharides into monosaccharides. Think of starch as a tree; amylase works on digesting starch units (i.e. saccharides) from the end of branches inwards until it comes to a fork where it stops as the links are different. Glucoamylase breaks down these "fork" links so starch digestion is complete. Amylase and amyloglucosidase should always be taken together.
	Lactase found in babies, plants and certain microbes	Digests the milk sugar lactose into galactose and glucose. Lactase is naturally produced in the digestive tract of infants (unless they have congenital lactase deficiency). However the LCT lactase producing gene activity decreases into adulthood so that many adults are unable to effectively digest lactose. For many this results in symptoms of lactose intolerance.[13,26]
	Alpha galactosidase found in certain microbes	Hydrolyses raffinose, stachyose and verbascose in legumes, whole grains and some vegetables into simple sugars glucose, galactose and fructose. Known to reduce gas production when eating fermentable carbohydrates.[27]
	Invertase (type of sucrase) - found in humans, plants and certain microbes	Breaks down sucrose and maltose into fructose and glucose.
Fibrolytic enzymes	**Phytase** found in plants and certain microbes	Digests phytic acid from nuts, seeds, grains and cereals such as bran and wheat into myoinositol and phosphates. Phytic acid is considered an "anti-nutrient" as it binds essential minerals, such as zinc, resulting in decreased bioavailability, i.e. reduced absorption in the gut.
	Cellulase found in plants and certain microbes	Breaks down cellulose, a plant fibre found in fruit and vegetables. Chitin, a structural component of Candida albicans yeast cell walls[28,29] has virtually identical structure to cellulose.[30] Cellulase may therefore help reduce Candida infection.

Understanding digestive enzyme supplements

Plant versus animal digestive enzyme supplements

Digestive enzyme in supplements can be derived from animal (pancreatin) or plant sources.[13] Pancreatin, a mixture of pancreatic digestive enzymes, is usually bovine (cow) or porcine (pork) in origin. Animal pancreatic digestive enzymes work in a limited pH range (see table 2) as found in the small intestine but not in the stomach, where the pH is more acidic. However plant enzymes can operate efficiently in a wider range of pH 2-11. This means that they have digestive activity in the stomach as well as the small intestines. Plant and microbial enzymes are also suitable for vegetarians with no cause for concern about potential contamination of animal derived material. This makes plant and microbial digestive enzymes the clear choice for digestive support.

Safety of microbial digestive enzymes

Some digestive enzymes used in supplements are derived from microbial sources (Table 3). This is because there are a limited number of plant digestive enzymes, namely proteases including bromelain from pineapples and papain from papaya. This means microbial derived digestive enzymes from sources such as the Aspergillus oryzae and Aspergillus niger fungi are used in many supplements. They provide an extremely important source of vegan digestive enzymes that help us to digest many foods that are not broken down by our own digestive enzymes. For example gluten proteases to break down proteins such as gluten and carbohydrases such as lactase to help us digest the milk sugar lactose.

The question you might well be thinking is are these sources of enzyme safe for human consumption? The answer is very much yes. Digestive enzymes extracted from microbial sources, such as Aspergillus fungi, are grown in sterile and safe laboratory conditions. Fungal enzymes are taken from strains that do not produce mycotoxins and have been given the GRAS (Generally Recognised As Safe) label by the Food and Drug Administration (FDA).

In fact these purified fungal enzymes have been used in food industry for years to ferment foods (e.g. miso and tamari and soya sauce)

Microbial digestive enzymes can also break down more fat, carbohydrates, and protein (10-1000 times more potent) in the broadest pH range (~pH 2-11) compared to plant and animal sources of digestive enzymes. This makes the combination of plant and microbial digestive enzymes a powerful tool to support digestion.

Benefits of broad spectrum plant digestive enzyme supplements

Several studies have shown that supplementing with a range of different digestive enzymes is extremely beneficial to digestion and health. In one experiment a gastrointestinal model simulating the physiological conditions of the stomach and small intestines was used to investigate the effects of enzymes and optimal stomach and pancreatic conditions on digestion of a meal.[31] Under conditions of optimal stomach and pancreatic conditions the enzyme supplement improved carbohydrate digestion but only slightly improved protein digestion compared to an identical meal put through the system without digestive enzyme supplement.

However, under impaired physiological conditions the enzyme supplement significantly improved both carbohydrate and protein digestion compared to when no enzyme was used. The microbial and plant enzyme activity was also shown to be active in both the stomach and small intestine part of the model. Even though this was conducted in a laboratory model it gives an insight into the importance of supporting digestive enzyme levels especially when physiological conditions such as pH and temperature are disrupted.

Human studies using plant and microbial enzyme combinations show that digestibility of food and nutritional status is enhanced in patients. In fact in one study of elderly people in a nursing home showed how a broad-spectrum digestive enzyme enhanced nutritional status and also correlated with raised serum lymphocyte counts suggesting an improvement in immune function.[32] These positive changes were reversed when the enzyme supplement was withdrawn.

In a double-blind, placebo-controlled human trial, an enzyme supplement containing proteases, carbohydrases and lipase derived from microbial sources was administered with meals to a group of hospital patients reporting gastrointestinal symptoms.[33] At 8 weeks, global improvement scores were significantly higher in the enzyme group than in the placebo group. Symptoms reduced by the enzyme preparation included abdominal pain, nausea, vomiting, heartburn, bloating, flatulence, and loss of appetite.

Importance of digestive enzyme potency

Measuring enzyme activity is a complex task but vital task, necessary for understanding how choose an efficacious and therefore value for money supplement. Knowing the activity of each enzyme contained within a supplement is equally as important as knowing the types of enzymes that are included! The activity (or potency) is a measure of how much enzyme is needed to accomplish a specific reaction within a specified time. Fortunately assays have been developed to measure enzyme activity ensuring standardisation and consistency of enzyme activity. For example one Dextrinizing Unit (DU; Table 4) for amylase activity is defined as number of grammes of soluble starch digested per hour at 300oC and pH 4.6. Hemoglobin Units (HUT; Table 4) measuring protease activity is based on 30 minute hydrolysis of hemoglobin substrate at pH 4.7 and 400oC. We do not need to know all the individual assays, rather just be sure that the FCC units are used in any digestive enzyme formula you might be considering.

The Food Chemical Codex (FCC)[34] is the industry standard for measuring enzyme activity. Each enzyme is assigned their own FCC potency (activity) unit (Table 4). This not only demonstrates the potency or amount of activity of each enzyme in a particular product but also allows comparison between different FCC labelled products.

Unfortunately there is currently no regulation of enzyme activity in the food supplement industry. This can make choosing a supplement a bit of a lottery. It is for this reason that one should always choose a reputable brand that states all enzyme activity in FCC units so the activity and not just the weight of the enzyme is known. In fact if the product just states the weight of the enzymes (e.g. in milligrams, mg) this tells you nothing about the actual activity. That means you might choose a digestive enzyme supplement that contains 40mg lipase over the one that contains 20mg lipase because you would think the bigger dose of lipase would have twice the activity. However, every enzyme preparation can have different activities so you would not know the real potency of either lipase dose unless the FIP FCC unit was stated.

Table 4: FCC digestive enzyme potency units

Enzyme	FCC unit
Amylase	Dextrinizing Unit (DU)
Amyloglucosidase	Amyloglucosidase Unit (AGU)
Lactase	Acid Lactase Unit (ALU)
Invertase	Invertase Activity Unit (InvU)
Alpha-galactosidase	Galactosidase Units (GalU)
Lipase	Federation Internationale Pharmaceutique (FIP)
Vegetable proteases	Hemoglobin Unit (HUT)
Gluten proteases	Glutaminase Units Endoproteinase Units
Bromelain	Gelatin Digesting Unit (GDU)
Cellulase	Cellulase Unit (CU)
Phytase	Phytase Unit (FTU)

This means if you choose a digestive enzyme supplement that states enzyme activity in FCC units you are making an informed decision and can be safe in the knowledge that the activity of each enzyme has been carefully measured and standardised.

Proteases and acidity within the body

Protein digestion has been proposed to contribute to an increase in acidity within the body. However a naturopathic approach to health should aim, broadly speaking, to promote alkalinity within the body. So where does the use of proteases within a digestive enzyme supplement fit with the naturopathic philosophy?

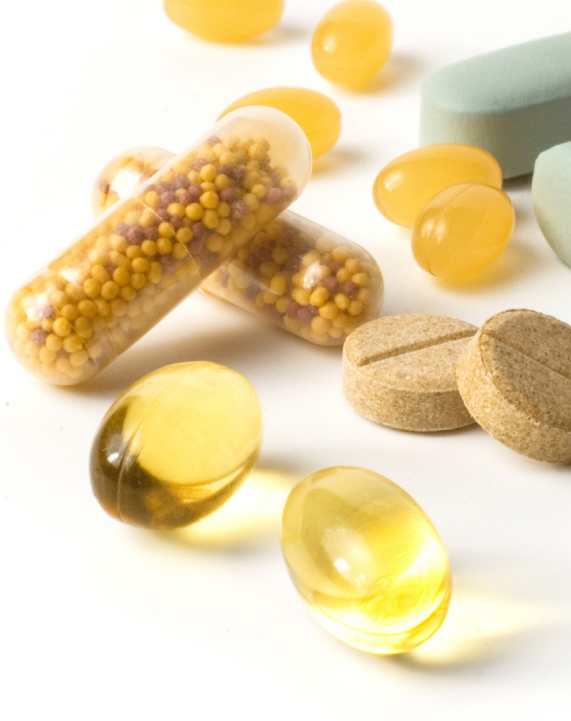
Digestion of proteins within the gut is required to supply our bodies with amino acids. These building blocks are central to supply of enzymes throughout the body, including those that regulate pH levels in the cells and blood, and structural proteins such as those found in muscles. Amino acids are also required for metabolism and energy production and are chemical messengers in the brain (i.e. neurotransmitters) in their own right. It's for these reasons that poor protein digestion may greatly impact on physiological, biochemical and psychological health.[35,36]

We have explored how digestive enzymes levels are greatly reduced at times of stress, illness and with the ageing process[37] so even though Western diets can be high in proteins, especially from excessive consumption of the difficult to digest animal proteins, protein deficiency from poor digestion can still easily occur. For this reason digestive enzyme supplements containing carefully balanced levels of protease can help ease the burden on overworked endogenous protease enzymes. Proteases can also digest protein found in other organisms such as the coating on certain viruses, toxins from dead bacteria and other microorganisms, and certain harmful substances produced at sites of injury or inflammation within gut. This makes adequate levels of proteases vital for protecting and balancing our gut flora.

Incomplete protein digestion within the small intestine may also result in the transport of undigested or partially digested proteins into the colon. If this occurs then putrefactive fermentation by certain strains of gut bacteria may lead to the creation of toxic compounds within the colon that can be absorbed into the body – a form of persistent autointoxication will occur if protein digestion, as well as balancing protein intake through the diet, is not addressed.

Outlining the importance of proteases to our health should demonstrate the necessary inclusion of carefully balanced levels of plant and microbial derived protease enzymes in a broad-spectrum digestive enzyme supplement. Plant and microbial proteases have a much wider pH activity range compared to animal derived allowing for more efficient and complete protein digestion.[2]

So you could say that the benefits of supplementing with proteases outweigh the slight rise in acidity associated with enhanced protein digestion. Other methods can be used to counteract any potential pH change such as consuming a diet rich in alkalising foods and including a daily concentrated greens powder in a homemade smoothie or fresh juice. See the end of this newsletter for some easy and tasty recipes.



The many health benefits of digestive enzyme supplements

Digestive enzyme supplements are widely reported to be of benefit in many different health conditions including:

- Irritable Bowel Syndrome (IBS)
- Digestive disturbances including indigestion, flatulence and bloating
- Coeliac disease
- Food intolerance and allergies
- Seasonal allergies
- Weight management
- Autistic Spectrum Disorders (ASD)
- Exocrine Pancreatic Insufficiency (EPI)
- Non Alcoholic Fatty Liver Disease (NAFLD)
- Stress

Who should take digestive enzyme supplements

Many naturopaths consider digestive imbalances to be at the root of all disease.[2] This means that we should be taking utmost care of our digestive tract from the mouth right down to the other end of the tube! There are many different processes that make up digestion ensuring adequate levels of stomach acid to support digestion and also kill any unwanted pathogens that we might ingest producing bile to help emulsify fats ready for digestion by lipase as well as to balance pH in the small intestines as well as ensuring the optimal balance of bowel flora in both the small and large intestines.38 Underpinning this process is the need to ensure the food is properly broken down so that we may absorb the precious nutrients locked within. This is the sole role of digestive enzymes produced mainly the pancreas but also in the salivary glands and stomach.

As we've discussed at length in previous sections of this newsletter digestive enzyme production and function take a battering from many events that we experience on a daily basis such as stress, illness and the ageing process. This means that digestive enzyme supplements are suitable for the majority of adults. There are a few cases where certain digestive enzymes are not deemed suitable. These mainly include the presence of ulceration in the digestive tract as seen with stomach ulcers and ulcerative colitis. This is due to the fact that proteases may exacerbate inflammation of the gut mucosal layer when ulcers have already damage this tissue lining. Healing of the gut lining should take place first with dietary approaches such as removing offending foods like gluten and dairy, which promote tissue damage and ulceration of the gut in sensitive individuals. Phosphatidyl choline (lecithin) powders have also been shown to support the repair of damaged stomach and gut tissue as well as certain gut supporting botanicals like turmeric.[2,39]

What digestive enzymes should we take?

It seems we are still a nation of carbohydrate lovers. The DEFRA Food Survey (2011)[40] found that carbohydrates, especially bread, pasta and cereal products, constituted around 45-47% of the average British daily diet followed by around 35-38% fats and 15% protein, derived mainly from animal sources. These figures were collected from 6,000 sample households in the UK using self-reported diaries supported by till receipts of food purchases, and including food eaten out, over a 2 week period.

Whilst dietary intake varies from person to person it is important to know the order of macronutrient consumption in the diet so that optimal digestion can be supported.[41] This means that if there is call for digestive enzyme supplementation then a broad-spectrum supplement high in a variety of carbohydrases is going to benefit many people. The same principal could be applied if the diet is rich in vegetable and plant matter. We do not naturally produce digestive enzymes to support digestion of plant carbohydrases and fibres so a broadspectrum supplement containing cellulase and phytase will support digestion and increase mineral bioavailability for people consuming these diets. This also rings true for people switching to a more health-promoting diet rich in plant matter. A change in diet places new challenges on the digestive system, as do foods rich in fats, proteins and carbohydrates. This means supporting digestion with a natural vegan broad-spectrum digestive enzyme supplement may well be advised.

When to take digestive enzyme supplements

Digestive enzyme supplements can be taken on a daily basis to support natural digestive processes. Taking a broad-spectrum supplement that contains a variety of carbohydrases, lipases and proteases along with fibrolytic enzymes reduces the number of individual supplements one needs to take whilst also saving money! Digestive enzymes should be taken just before or during the main meals of the day. Many report the rapid benefits of taking broadspectrum plant digestive enzyme supplements. However, it is highly recommended to continue supplementing with digestive enzymes on a daily basis to continue to support the complex and delicate balance of digestion and ensure nutrients from the food we eat are available from the food we eat for absorption through the digestive tract.

Do digestive enzyme supplements override the natural production of digestive enzymes?

This is a fair question to ask and one always needs to remember to use digestive enzyme supplements, or any food supplements for that matter, with a truly naturopathic approach. That is using supplements to support and enhance the body's natural systems and not to override or suppress them. It's for this reason that plant and microbe-derived digestive enzyme supplements are so useful in a naturopathic programme to support optimal health.

These types of enzyme work with the body, as many of the plant and microbe enzymes are not naturally produced by the pancreas or salivary glands (for example gluten proteases and lactase) and therefore complement and enhance the actions of existing levels of digestive enzymes. Also the levels of natural digestive enzymes are controlled by hormones not a negative feedback system where high levels of digestive enzymes switch off secretion of enzymes by the pancreas or salivary glands. Whether from internal or external (i.e. supplemental) enzymes, complete hydrolysis of food is the indicator for the hormones secretin and cholecystokinin to signal the reduction of pancreatic juice secretion. This means that digestive enzyme supplement supports digestion and does not inhibit it.

Remember also the importance of having enough amino acids, the building blocks for protein, present to make enzymes in the first place. Supplementing with a broad-spectrum enzyme supplement containing some proteases will therefore help raise levels of amino acids ready for synthesis of new proteins, including pancreatic and salivary gland digestive enzymes. This should leave little room for doubt that long-term supplementation with plant and microbe digestive enzymes enhances the body's own digestive processes paving the way for increased bioavailability of nutrients to benefit health.

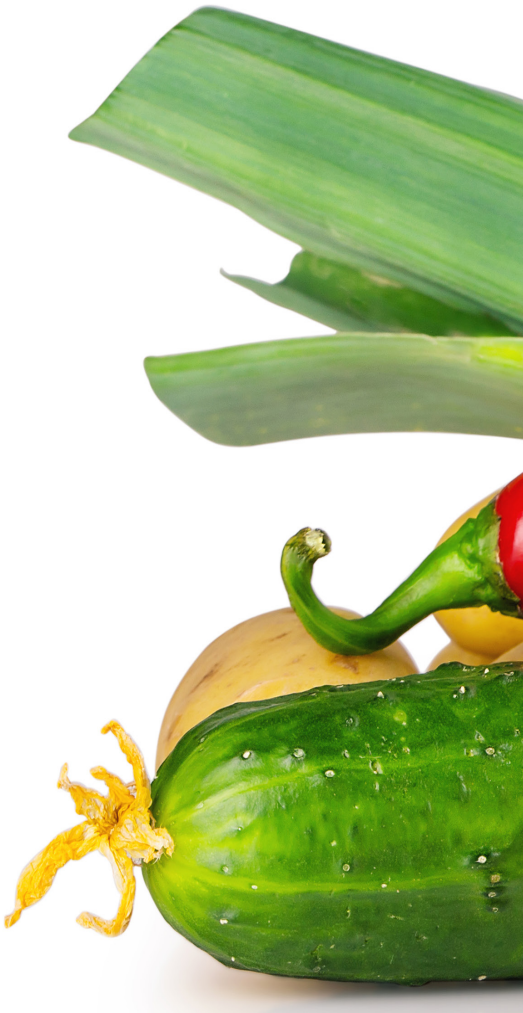
Achieving digestion perfection

Synergetic supplements

There is no doubt that daily supplementation with a broad-spectrum plant and microbe-derived digestive enzyme supplement can be very supportive of digestion. However digestion is not solely down to digestive enzymes but requires synergistic actions of stomach hydrochloric acid, bile salts, including lecithin, and a healthy lining to the GI tract to enable vital nutrients to be absorbed. With this in mind, complementary digestion supporting supplements that work synergistically with a vegan digestive enzyme formula includes:

- Betaine and pepsin and zinc citrate to support gastric hydrochloric acid levels and protein digestion production.[2]
- Mixed strain probiotic supplement to support the levels of health promoting gut bacteria.[38]
- Aloe Vera juice – an all round digestive support helping to heal the gut lining, support growth of beneficial gut bacteria and digestion of proteins reducing the incidence of putrefactive fermentation.[42]
- Colon supporting herbs like turmeric and ginger.[2]
- Lecithin powder high in phosphatidyl choline to support digestion of fats as well as healing the lining of the stomach and gut.[39]

Supporting all areas of digestion with changes in the diet, complementing supplements and also addressing lifestyle factors such as stress provides the foundation to any truly effective naturopathic nutrition programme. For more information on these programmes then please consult a naturopathically trained Nutritional Therapist. See the Federation of Nutritional Therapy Practitioners (www.fntp.org) for more information.



Supporting optimal digestion checklist

- Address stomach acid levels to enhance digestion and support enzyme actions (e.g. 1tsp organic apple cider vinegar before a meal or betaine and pepsin supplement with meal, daily Aloe Vera juice).
- Support digestive enzyme levels to enhance digestion of all macronutrients, increase mineral bioavailability and digest common dietary allergens including lactose and gluten (e.g. include some raw foods rich in natural plant enzymes – see recipe section, supplement with plant and microbe broad-spectrum digestive enzyme supplement).
- Support beneficial gut bacteria through fermented foods like natto and kefir, and ones containing prebiotics like onions and garlic, reduce stress and take daily multi-strain probiotic supplements.[2,38]

Recipes to support digestion perfection

Beetroot and apple juice

Beetroot is high in betaine, and lecithin supports fat digestion.

Ingredients:
- 12 apples
- 1 medium raw beetroot
- ½ cucumber
- 1 stick of celery
- 1tsp lemon juice*
- 1tsp phosphatidyl choline enriched lecithin powder*
- 1tsp organic spirulina powder*
- Plant digestive enzyme formula (capsule contents can be mixed into juice)

*optional

Method:
- Juice the apples, beetroot, cucumber and celery.
- Mix in lemon juice, lecithin powder, spirulina and digestive enzyme capsule contents and enjoy.

Bitter leaves salad with apple and walnuts

Bitter foods, such as radicchio, lamb's lettuce, rocket and frisée lettuce, trigger the production of digestive enzymes in the stomach and pancreas. Enjoy this salad as a light meal or accompaniment with a piece of baked fish.

Ingredients:
- 100g mixed salad leaves of rocket, watercress and lamb lettuce
- 2 red and white chicory, washed and leaves separated
- 1 eating apple cored and chopped
- 50g walnuts, roughly chopped
- 3tbsp olive oil
- 1tbsp organic apple cider vinegar
- 1tsp wholegrain mustard
- 1 tsp phosphatidyl choline enriched lecithin powder*

*optional

Method:
- Toss salad leaves and chicory in bowl along with apples and walnuts
- Whisk olive oil, mustard, apple cider vinegar, and lecithin powder
- Spoon over salad and enjoy

Papaya and pineapple smoothie

Ingredients:
- ½ papaya
- 2 slices fresh pineapple
- Handful of fresh mint leaves
- ½ lime juice
- 10p size piece of fresh ginger root
- 1 tsp phosphatidyl choline
- enriched lecithin powder*
- Plant digestive enzyme formula (capsule contents can be mixed into smoothie)

*optional

Method:
- Place all the ingredients in a blender. Whizz until smooth. Add additional filtered water to achieve desired consistency – a tasty breakfast and much healthier alternative to toast and jam!

If you have any questions then please contact the nutrihub team on 0800 043 8549 or email education@nutrihub.org

This education article was co-written by Dr Elisabeth Philipps PhD and the nutrihub team.

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