The Chemistry Behind Digestion and Pancreatic Enzymes

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Abstract

_____Hydrolysis of nutrients occurs due to different pancreatic enzymes that help us to break down and digest foods. There are three types of enzymes, each with a unique purpose, that cause these reactions and allow us to absorb the nutrients we need for survival. Each has different enzymes that fit under their category based on what they do. Those that digest protein are proteases, those that digest fat are lipases, and those that digest carbohydrates are amylases. The pancreas is a necessary organ that contributes greatly to the digestion of food due to the enzymes it secretes in the pancreatic juice. The pancreatic juice is released into the small intestine, where the enzymes are activated and work along with bile and hormones in order to completely digest food for nutrients.

Introduction

The process of digestion is an essential part of surviving, as we need the nutrients provided to us through eating in order to survive. In a healthy person, food travels from the mouth, through the digestive system until the nutrients are removed and all that is left is waste, which is then excreted by the body. Throughout this process, many chemical reactions take place in order to break down the food, starting with saliva, and continuing as it passes through the large intestine. These chemical reactions are sped up due to enzymes, the biological catalysts that lower the amount of energy it takes for the reaction to occur. Enzymes are specifically dedicated to a certain reaction and are secreted at different points during digestion. Many enzymes are secreted by the pancreas, a pink-grey organ that is essential to the breakdown and digestion of food. Without a sufficient amount of pancreatic enzymes, a person would have very serious and potentially life threatening digestive issues. For this reason, many people with pancreatic enzyme deficiency are prescribed enzymes by a doctor. These supplemental enzymes, such as Creon, Pancreaze, or Pertyse can provide then enzymes needed to break down food that the person cannot produce themselves. Some reasons for the pancreatic enzyme deficiency are pancreatic cancer, pancreatitis, Whipple Procedures (the partial removal of the pancreas and other digestive organs, usually to remove cancerous tumors or tissue) , a total pancreatectomy (the total removal of the pancreas), and

Cystic Fibrosis. [1] Many times, people who have these procedures or illnesses have malabsorption, which means that although they eat, they are not absorbing the nutrients from the food and may lose weight. The enzymes help resolve this issue by breaking down the food so that it can be properly absorbed as well as properly excreted. There are many different enzymes secreted by the pancreas into the small intestine, each with separate and specific things to break down, whether that be proteins, carbohydrates, or fats. The chemical reactions that occur are unique to each enzyme and what it is helping break down. Each depends on the molecular structure of the enzyme, which itself is a protein, as well as the structure of the protein, carbohydrate, or fat that is being broken down. The pancreatic enzymes work together with enzymes from other parts of the digestive system as well as with bile acid from the liver and hormones that help the digestive system create and transport the necessary nutrients.

Body

There are three main enzymes that are secreted by the pancreas in the pancreatic juice to the small intestine. Protease, Lipase, and Amylase are the most abundant and each have their own purpose. Protease breaks down protein and keeps the intestines healthy by getting rid of bacteria and other parasites.

Lipase breaks down fat by working together with the liver bile. The fat is then processed and absorbed by the body. Amylase, which is also found in saliva as well as in pancreatic juice, breaks down carbohydrates into sugars, which is why when a piece of bread is left in your mouth for a long time, it begins to become sweet."...the content and the specificity of the digestive enzymes remain under amazing control so that humans can adapt to a wide range of diets, whether they are carnivorous or vegetarian". [2] Each of these pancreatic enzymes- protease, lipase, and amylase- is able to break apart a certain type of chemical bond in complex nutrients.

Because protein makes up around 10% of calories consumed in a Western diet, it is no surprise that proteases make up 80% of the pancreatic enzymes secreted. Proteins eventually break up into

[1] The Pancreatic Cancer Action Network
[2] Human Pancreatic Digestive Enzymes by David C. Whitcomb and Mark E. Lowe

amino acids, which are necessary components for growth, development, and energy. This means that it is essential for those proteases to completely and correctly break the proteins down into amino acids, otherwise the body will not be properly nourished and will therefore not function correctly. Proteases are especially effective in breaking down proteins such as meat because they are helpful in digesting high collagen content parts of the meat such as the muscles or tendons. There are two types of groups of proteases secreted by the pancreas- endopeptidases and exopeptidases. [3] Both are stored as inactive until stimulated, majority of the time by trypsin. The trypsin is not activated until the enzymes reach the duodenum, as early release could cause the digestion of human tissue and disrupt enzyme systems. An example of this is early activation in the pancreas could cause fatal acute pancreatitis, or inflammation of the pancreas. Endopeptidases such as trypsin, chymotrypsin, and elastase cleave peptide bonds that are adjacent to certain amino acids in proteins. Exopeptidases, like carboxypeptidases, cleave bonds of peptides at the carboxyl terminus of proteins.

Trypsinogen, or the inactive form of trypsin, is the most important enzyme because it helps regulate the other enzymes involved in digestion and is 19% of the pancreatic juice, making it the most abundant. It has to be activated at just the right time to insure that no human tissue is broken down. It is activated by an acid residue that leaves a negative charge for calcium to bond to, which enhances the ability of the activation peptide to cleave and hydrolysis to occur. It also is pH dependent, as a certain pH, usually between 7.5 and 8.5, ensures ideal conditions. Because trypsin is so vital to the digestion process, there are multiple forms, all with similar protein structures and genetic sequences. 66% of trypsin activity is cationic trypsinogen, 33% is anionic trypsinogen, and less than 5% is mesotrypsinogen. Although all very similar, there are certain differences between the three. For example, cationic trypsin does not degrade as quickly as anionic trypsin, and mesotrypsin has the unique ability to be resistant to a trypsin inhibitor called pancreatic secretory trypsin inhibitor (PSTI).[4] Recently Pancreasin, a new enzyme that has properties similar to a trypsin enzyme, was discovered but not enough research has been conducted to know the biology and physiology. Proteases like trypsin are extremely effective which is why

[3] Digestive Enzymes by Pandol SJ
[4] Whitcomb and Lowe believe that this is possibly caused by “substitution of an Arg ...compared to Gly”

it is important that they are only active in parts of the body that will not be affected or harmed by them. So as the contents of the intestine reach the colon, protease activity stops in order to protect the intestines. Types of protease enzymes, their actions, and products are shown below.[5]

Enzyme	Action	Product(s)
Trypsin Cationic Trypsinogen Anionic Trypsinogen Mesotrypsin Pancreasin	Endopeptidase; cleaves internal bonds at lysine or arginine residues	Oligopeptides
Chymotrypsin	Endopeptidase; cleaves bonds at aliphatic amino acid residue	Oligopeptides
Elastase Elastase 2A, 2B, 3A, 3B		
Carboxypeptidase A A1, A2, A3	Exopeptidase; cleaves aromatic amino acids from the carboxyl terminal ends of proteins and peptides	Aromatic amino acids and peptides
Carboxypeptidase B B1, B2		Arginine, lysine, and peptides

The average diet consists of over 100g of fat, which is broken down in the digestive system by lipase. Lipase can come from two different places in the digestion process. It is present in the stomach and in the pancreatic juice that is transported to the small intestine to break down food. Gastric lipases are the lipase that comes from the stomach, and it is much less powerful than pancreatic lipases, which are created by the pancreas in large amounts. Although gastric lipases contribute much less to digestion than pancreatic lipases, they still release anywhere between 10-30% of the fat that is consumed before it leaves the stomach. After this, it passes through the small intestine, where bile and pancreatic enzymes digest the rest of the fat. However, digestion by the gastric lipases helps facilitate hydrolysis caused by pancreatic enzymes, and in many cases of pancreatic enzyme insufficiency, gastric lipases can help compensate. For example, newborns often do not have sufficient levels of pancreatic lipase, and therefore rely on gastric lipases to digest and absorb fats.

The pancreatic lipases are responsible for most of the digestion of fat a person has in their diet. Lipases hydrolyze triglyceride molecules, which are what fat is composed of, into two fatty acid molecules and a monoglyceride with a fatty acid. The lipase binds to the oil droplet and requires bile and colipase to fully break apart the acid. The bile increases the surface area the lipase can react with. Colipase allows

[5] Table from Human Pancreatic Digestive Enzymes by Whitcomb and Lowe Page 2

lipase to continue to be active even when inhibitory substances are present. Although colipase is not an enzyme, it too is secreted by the pancreas along with lipase and other enzymes.

The lipase that has been studied the most in depth and is the most well-known is pancreatic triglyceride lipase. The crystal structure of this lipase allows it to remain inactive until it comes in contact with an oil water interface where it will then begin to break down the fat. Another pancreatic lipase is carboxyl ester lipase. Although not as much research has been done on this enzyme and the structure is not known, it has been discovered that it has the ability to hydrolyze glycerolipids with long chains of fatty acids and monoacylglycerols. Another major lipase are phospholipases, which catalyze the reaction of the bonds of phospholipids.

The last major enzyme of the digestive system is amylase, found in the pancreatic juices and also in saliva. Salivary and pancreatic amylase have differing weights and mobility but do the same job. Salivary amylase can digest up to 50% of the starch and carbohydrates. Unlike other enzymes such as proteases and lipases, amylase does not have an inactive form, which means that it is constantly active as it passes through the digestive system; however, unlike proteases and lipases, it is not as dangerous and will not digest human tissue, so this is not an issue. Amylase has three domains, two of which bind to calcium, and one of which has an unknown purpose. Amylase hydrolyzes glycosidic links between every other bond of hydrogen and oxygen. Amylase enzymes result in a final product of dextrins, a mix of different glucose units after digestion by both the salivary and pancreatic enzymes.

Conclusion

Pancreatic enzymes, such as protease, lipase, and amylase, are essential to proper digestion of foods, each with a separate focus on what it is chemically breaking down. Protease activates at just the right time in order to break down the proteins of a diet. Lipase from both the stomach and the pancreas work to digest fat so as to receive the proper nutrients. Amylase is constantly active in saliva and pancreatic juice to break down carbohydrates. All of these enzymes are necessary in order for a person to be in good health, so any deficiencies in these enzymes will result in serious medical symptoms, and medication would need to be taken in order to do the work of the enzymes. These enzymes affect every

single person, especially those who have malfunctioning pancreases. People with pancreatic cancer, pancreatitis, or cystic fibrosis most likely do not have sufficient amounts of these enzymes and have problems digesting foods. Diseases like pancreatitis are extremely painful and potentially fatal, and can be caused by these enzymes not working properly- if protease is activated to soon, it can cause inflammation in the pancreas, also known as acute pancreatitis. More research should be done on these enzymes to learn more about their structures and how they are activated in order to solve the problem of activation at inappropriate times. The research could also help to create medications that can function as enzymes for those with deficiencies. Digestion is a daily process that provides us with the nutrients necessary for survival, which is why these enzymes are so important. Every single person in society is affected by these enzymes because they ensure proper health, which is something that we all wish for in our lives.

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