COMMENTARY

Ketosis and Carbohydrate Consumption

The ketogenic diet is often classified as a diet that promotes ketosis by restricting the consumption of carbohydrates and protein and increasing the consumption of fats, and while this is somewhat correct, it also promotes some misconceptions of ketosis.

An individual can still enter ketosis even if they ate an all-carbohydrate diet, and zero fat or protein. To understand how this may be, it is important to first review some general concepts regarding the metabolism of carbohydrates and ketosis.

METABOLISM OF CARBOHYDRATES AND KETOSIS

A considerable amount of energy within the body is devoted to breaking down the components in food so that they can be used to help create adenosine triphosphate (ATP) molecules, which are the fuel for many chemical reactions throughout the body. This process generally starts with the physical breakdown of food within the mouth (known as mastication), and is followed by chemical reactions to break down these components with the help of gastric acid (primarily hydrochloric acid) and salivary/pancreatic enzymes, which help breakdown complex molecules (like polysaccharides, such as starch) into simpler ones (i.e., monosaccharides like glucose) for easy absorption within the upper region of the small intestine, also known as the duodenum.

The rate at which this absorption occurs depends primarily on the contents of the meal, with meals high in protein and fiber resulting in longer gastric emptying times. After the resulting chyme is emptied into the small intestine and absorbed via the microvilli within the duodenum, it will be transported to the liver via the hepatic portal vein for further processing before it reaches the blood for systemic circulation.

This leads to a rise in blood glucose, which typically results in the release of the hormone insulin from the pancreas which binds to insulin receptors on the cell membranes of certain tissue cells and results in a cascade of reactions that ultimately leads to the diffusion of glucose molecules down the concentration gradient of the cell membrane via the corresponding GLUT4 channels and these molecules are then processed within the cell itself through a series of complex chemical reactions, which make up cellular respiration such as glycolysis, the citric acid cycle, and the electron transport chain. The latter two occur within the mitochondria of the cell, and it is specifically within the electron transport chain where the enzyme acetyl coenzyme A is reverted back to its precursor in order to produce molecules of ATP.

COMMENTARY

Ketosis and Carbohydrate Consumption

The ketogenic diet is often classified as a diet that promotes ketosis by restricting the consumption of carbohydrates and protein and increasing the consumption of fats, and while this is somewhat correct, it also promotes some misconceptions of ketosis.

An individual can still enter ketosis even if they ate an all-carbohydrate diet, and zero fat or protein. To understand how this may be, it is important to first review some general concepts regarding the metabolism of carbohydrates and ketosis.

METABOLISM OF CARBOHYDRATES AND KETOSIS

A considerable amount of energy within the body is devoted to breaking down the components in food so that they can be used to help create adenosine triphosphate (ATP) molecules, which are the fuel for many chemical reactions throughout the body. This process generally starts with the physical breakdown of food within the mouth (known as mastication), and is followed by chemical reactions to break down these components with the help of gastric acid (primarily hydrochloric acid) and salivary/pancreatic enzymes, which help breakdown complex molecules (like polysaccharides, such as starch) into simpler ones (i.e., monosaccharides like glucose) for easy absorption within the upper region of the small intestine, also known as the duodenum.

The rate at which this absorption occurs depends primarily on the contents of the meal, with meals high in protein and fiber resulting in longer gastric emptying times. After the resulting chyme is emptied into the small intestine and absorbed via the microvilli within the duodenum, it will be transported to the liver via the hepatic portal vein for further processing before it reaches the blood for systemic circulation.

This leads to a rise in blood glucose, which typically results in the release of the hormone insulin from the pancreas which binds to insulin receptors on the cell membranes of certain tissue cells and results in a cascade of reactions that ultimately leads to the diffusion of glucose molecules down the concentration gradient of the cell membrane via the corresponding GLUT4 channels and these molecules are then processed within the cell itself through a series of complex chemical reactions, which make up cellular respiration such as glycolysis, the citric acid cycle, and the electron transport chain. The latter two occur within the mitochondria of the cell, and it is specifically within the electron transport chain where the enzyme acetyl coenzyme A is reverted back to its precursor in order to produce molecules of ATP.

With all that in mind, even if an individual were to avoid all sources of fat and protein, they could still enter a state of ketosis and this is primarily because dietary fat and protein are not necessary for the creation of ketones. Rather, it is the restriction of a certain quantity of carbohydrates that is more important. This is because when the amount of glucose and glycogen is low within the available tissues, the liver essentially begins to produce glucose from other sources, such as amino acids, and fatty acids through gluconeogenesis, and blood levels of glucagon and epinephrine also begin to rise, while insulin levels begin to fall. As a result, more fatty acids are typically released into the blood from adipose tissue via lipolysis, which then allow for the generation of ketone bodies via ketogenesis.

"An individual can still enter ketosis even if they ate an all-carbohydrate diet, and zero fat or protein."

These free fatty acids are oxidized, specifically via beta-oxidation, and then converted into acetyl coenzyme A, which is then oxidized in the electron transport chain to produce ATP, which all occur within the cell mitochondria. Thus, having adipose tissue is enough to enter a state of ketosis. This is typically why the vast majority of keto experts classify a ketogenic diet as being one that involves consumption of less than 50 grams of carbohydrates per day, which is 200 kilocalories a day, and not as a diet that needs to have a sufficient amount of dietary fat and protein.

While most individuals consume the rest of their calories from fat and protein for maintenance, even if an individual were to avoid all sources of fat and protein and only eat 200 kilocalories of carbohydrates a day (which is again, 50 grams of carbohydrates), this would technically make their diet an all carbohydrate diet because there is no consumption of fat and protein.

And this is an important point because many discussions around the ketogenic diet give equal weight to the restriction of carbohydrates, and the increased consumption of fat, however, it is the restriction of carbohydrates that matters, not the consumption of fat, protein, or animal products.

Once again, this is important because if an individual wanted to go on a very low-calorie diet for a few days and also enter ketosis, they could do so by still eating food products with carbohydrates in them, instead of restricting all consumption of carbohydrates and eating high amounts of fat and protein.

Furthermore, it deemphasizes the consumption of fats, which are quite energy dense (at 9 kilocalories per gram) and which are more easily stored as fat when there is an energy excess in the diet, when compared to carbohydrates (which typically need to be converted into fatty acids when there is excess energy in the diet through the process of *de novo lipogenesis*, which is a highly inefficient process, but generally begins to become more efficient with more energy consumption). ■

Zad Rafi, BS in Neuroscience, Department of Population Health, NYU Langone, New York, NY. Department of Standards, The Paleo Foundation, Encinitas, CA.

ACKNOWLEDGEMENTS

I would like to thank Chris Masterjohn, Ph. D and especially his work with Mastering Nutrition Episode 22: Ketogenesis Isn't All About Carbs and Insulin for elucidating the mechanisms involved in ketosis.

With all that in mind, even if an individual were to avoid all sources of fat and protein, they could still enter a state of ketosis and this is primarily because dietary fat and protein are not necessary for the creation of ketones. Rather, it is the restriction of a certain quantity of carbohydrates that is more important. This is because when the amount of glucose and glycogen is low within the available tissues, the liver essentially begins to produce glucose from other sources, such as amino acids, and fatty acids through gluconeogenesis, and blood levels of glucagon and epinephrine also begin to rise, while insulin levels begin to fall. As a result, more fatty acids are typically released into the blood from adipose tissue via lipolysis, which then allow for the generation of ketone bodies via ketogenesis.

"An individual can still enter ketosis even if they ate an all-carbohydrate diet, and zero fat or protein."

These free fatty acids are oxidized, specifically via beta-oxidation, and then converted into acetyl coenzyme A, which is then oxidized in the electron transport chain to produce ATP, which all occur within the cell mitochondria. Thus, having adipose tissue is enough to enter a state of ketosis. This is typically why the vast majority of keto experts classify a ketogenic diet as being one that involves consumption of less than 50 grams of carbohydrates per day, which is 200 kilocalories a day, and not as a diet that needs to have a sufficient amount of dietary fat and protein.

While most individuals consume the rest of their calories from fat and protein for maintenance, even if an individual were to avoid all sources of fat and protein and only eat 200 kilocalories of carbohydrates a day (which is again, 50 grams of carbohydrates), this would technically make their diet an all carbohydrate diet because there is no consumption of fat and protein.

And this is an important point because many discussions around the ketogenic diet give equal weight to the restriction of carbohydrates, and the increased consumption of fat, however, it is the restriction of carbohydrates that matters, not the consumption of fat, protein, or animal products.

Once again, this is important because if an individual wanted to go on a very low-calorie diet for a few days and also enter ketosis, they could do so by still eating food products with carbohydrates in them, instead of restricting all consumption of carbohydrates and eating high amounts of fat and protein.

Furthermore, it deemphasizes the consumption of fats, which are quite energy dense (at 9 kilocalories per gram) and which are more easily stored as fat when there is an energy excess in the diet, when compared to carbohydrates (which typically need to be converted into fatty acids when there is excess energy in the diet through the process of *de novo lipogenesis*, which is a highly inefficient process, but generally begins to become more efficient with more energy consumption). ■

Zad Rafi, BS in Neuroscience, Department of Population Health, NYU Langone, New York, NY. Department of Standards, The Paleo Foundation, Encinitas, CA.

ACKNOWLEDGEMENTS

We thank Chris Masterjohn, Ph. D and especially his work Mastering Nutrition Episode 22: Ketogenesis Isn't All About Carbs and Insulin for elucidating the mechanisms involved in ketosis.