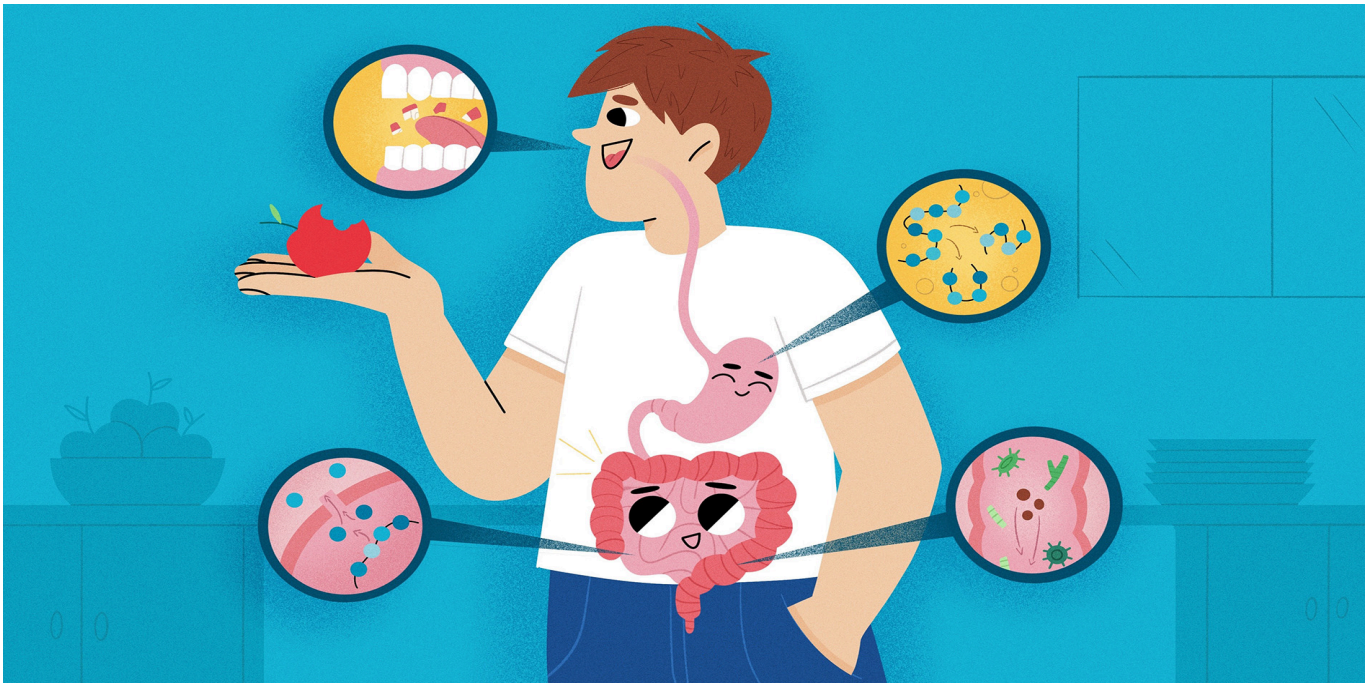
frontiers | Frontiers for Young Minds

HUMAN HEALTH
Published: 08 July 2024
doi: 10.3389/frym.2024.1386116



FROM CHEW TO POO—HOW A FOOD'S STRUCTURE CHANGES DIGESTION

Meinou N. Corstens [1*] ***and Ciarán Forde*** [2]

[1] *Food Process Engineering, Wageningen University and Research, Wageningen, Netherlands*

[2] *Human Nutrition and Health, Wageningen University and Research, Wageningen, Netherlands*

YOUNG REVIEWERS:

ARMAAN
AGE: 12

ELIZABETH
AGE: 12

LAUREN
AGE: 12

WARIS
AGE: 9

Have you ever wondered what happens to food inside your body? How does your body know what you have eaten? And why do you feel full after a meal? The digestive tract breaks down the foods we eat, absorbs their nutrients, and sends them to different parts of the body to keep us healthy and full of energy. The body knows how to handle each type of food so that only "leftovers" are turned into poo. A food's structure determines how fast foods are broken down. The body monitors this and sends messages to the brain to tell us if we feel full or hungry. You might think you are in control, but a food's structure manipulates how you eat and digest your food. In this article, we explain what is known so far about the effects of a food's structure.

THE MOUTH

Imagine eating your favorite breakfast. You chew every bite, breaking it into smaller pieces. Saliva is added to soften the pieces, so they

can stick together. You feel the **food texture** in your mouth, like crispy cornflakes, soft bread, dry toast, or creamy scrambled eggs. These textures feel different due to the way their nutrient building blocks are put together. Just like arranging the same pieces of LEGO into different patterns, the arrangement of **nutrients** gives each food a unique texture. Building blocks of foods are connected in much stronger patterns in solid foods than in liquid drinks, with many different structures and textures in between.

A food's texture determines how it will be broken down in the mouth. We change the way we bite and chew food before swallowing, depending on its structure [1]. For example, you chew raw, crunchy carrots for longer than softer, boiled carrots. When we eat softer foods, we eat faster and consume more **calories**. A food's structure is therefore crucial in determining how fast or slow you eat, and even how much food you eat. You can swallow when the small pieces of sticky food particles form a soft ball, called the **bolus**. Once swallowed, you can feel the bolus move down your throat on its way to the stomach. Then it is gone until you go to the toilet... but what happens in between?

FOOD TEXTURE

The overall appearance and structure of the entire food, like the crispy texture of cornflakes, the soft texture of bread, or the dry texture of toast.

NUTRIENTS

Essential building blocks of food, like fats, proteins, and carbohydrates, that give you energy and help your body grow, learn, and stay healthy along with vitamins and minerals.

CALORIE

A unit to describe the energy that is contained in the nutrients of a food.

BOLUS

The soft ball of small pieces of sticky food particles that is formed in the mouth.

THE STOMACH

Once swallowed, the bolus begins its journey through the digestive tract (Figure 1). It moves through a long tube into the stomach, where it is kneaded and mixed with digestive juices, forming a "food-soup". The digestive juices include acids and enzymes that break down the food further. The enzymes are like tiny machines that cut specific nutrients out of the small pieces of food. For example, the enzyme pepsin cuts long protein chains into smaller chains called peptides, while the enzyme lipase cuts fats into smaller fat molecules and fatty acids.

The stomach wall acts like a balloon—as more food enters, it can stretch. You can sometimes feel this happen during a meal, giving you what is sometimes called a "food baby" after dinner. Since we have no eyes inside our bodies, these stretch sensors play an important role in sending messages to the brain telling us when we feel full and regulating appetite. Foods also differ in the way they influence fullness. Foods with more water, such as fruits and vegetables, take up more space in your stomach, so they can make you feel full faster per calorie consumed. By contrast, foods higher in fat, like mayonnaise and butter, take up less space in your stomach, so it is easier to consume more calories. How long you feel full after a meal depends on the rate at which food leaves your stomach and is emptied into the small intestine. This is called the **gastric emptying rate**.

GASTRIC EMPTYING RATE

The speed at which food leaves the stomach and is emptied into the small intestine.

The gastric emptying rate is largely determined by the volume, calorie density and structure of the food-soup. Water does not contain any calories or structure, so it can sneak through the stomach very quickly.

Figure 1

The action of the various stages of the digestive tract to break down food. On the **left**, you can see the anatomy of the digestive tract. On the **right**, you can see how the food structure is broken down in each of the stages.

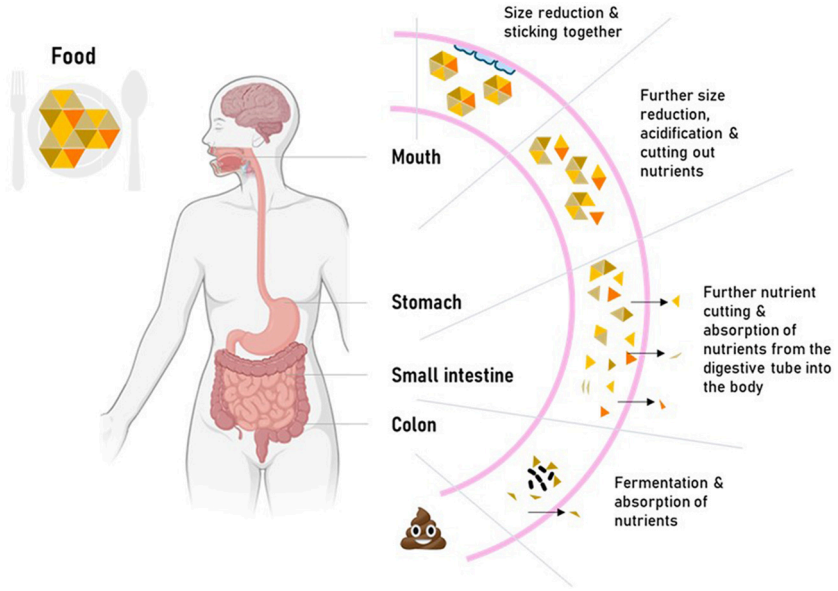


Figure 1

After just 10 min, half of the water you drink has already left your stomach [2]. Fluids with more calories than water, like milk or juice, empty in about 1–1.5 h. Food-soups of solid foods take 2–4 h to empty, depending on their structure. After about an hour, most foods have broken into small enough pieces (<2 mm) to continue their journey to the small intestine. Larger pieces (>5 mm) may only start to leave the stomach after 3 h [2]. Food structure can also affect the rate at which foods leave the stomach. For example, certain fats can float to the top of the food-soup, and this can speed up gastric emptying.

THE SMALL INTESTINE

In the small intestine, more digestive juices are added and mixed by the squeezing waves of the intestinal muscles. Imagine putting Play-Doh into a tube squishing it from one end to the other. These digestive juices contain different enzymes and substances to cut up the nutrients further and aid their uptake by the body. When nutrients are small enough, they can be taken up for use by the body through the wall of the small intestine and into the blood. This process is called **absorption**. Every nutrient is carried across the small intestine wall by a specific transporter, like a special door that only opens with the right key. On the other side of the door, the nutrient joins the bloodstream, which carries it to the cells in the body that need it. For example, amino acids from proteins are directed to help build new muscles, hair, or skin cells, whereas fats are used by the liver to produce energy. The small intestine's wall is covered in thousands of tiny, finger-shaped structures called villi, and even smaller finger-like shapes called microvilli. These structures increase the available surface for absorbing nutrients.

ABSORPTION

The uptake of nutrients from digested food over the wall of the small intestine into the blood.

Sensors detect the arrival of specific nutrients in the intestine and signal this information to the brain. This process works like a telephone call to the brain, to alert the body to what is coming, so it knows what to do with the nutrients. The more nutrients and the further down the small intestine they are detected, the longer you feel full. This mechanism is called the "intestinal brake", because it can put the brakes on eating. If you are interested in learning more about how the brain talks to the body, check out this Frontiers for Young Minds article.

FOOD MATRIX

The tiny parts and structures in food, like the air bubbles and network of bread substance in a slice of bread.

How fast food is digested and absorbed is largely determined by the arrangement of a food's nutrients at the microscopic level, which is called the **food matrix** [3]. When you look at the tiny details within bread, you see air bubbles surrounded by a spongy network of bread substance. If a tiny version of you walked through that bread network, you would see a smaller network of proteins and starches forming the food matrix. In foods with a sponge-like matrix with lots of holes in it, the digestive enzymes can easily go in and cut up the structures, which makes it easy to digest and absorb the nutrients from the food. However, many food matrices have holes that are too tiny, making it harder for digestive enzymes to break down the central structures, so they can only cut off the nutrients from the sides (Figure 2). This is especially the case for the plants that we eat, so these foods are digested very slowly. Researchers are currently trying to create the same kind of slow-digested matrixes for certain processed foods, to keep you full for longer [4].

Figure 2

Food matrix examples for bread and beans. Bread has lots of air bubbles and an open protein network, so digestive enzymes can easily get into the food matrix. Beans, however, do not have big spaces in their cell walls so the enzymes cannot get in easily. This makes beans more difficult to digest than bread (adapted from [3]).

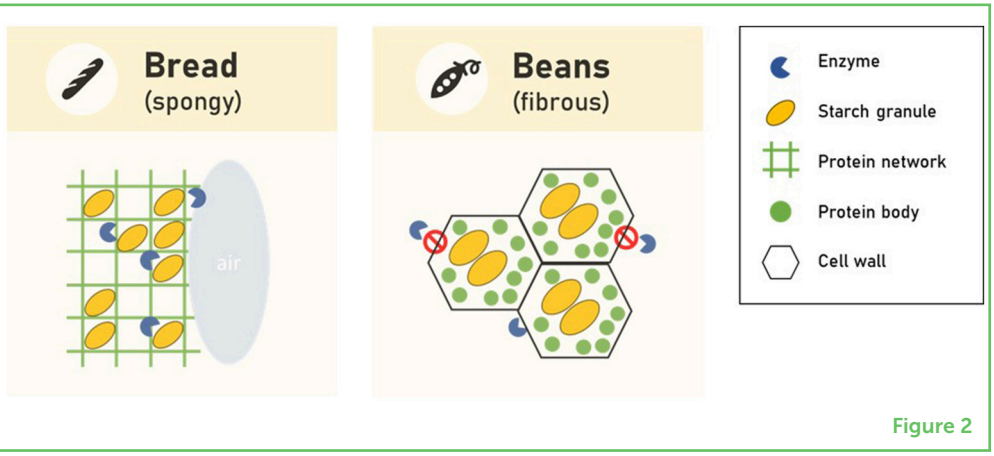


Figure 2

THE COLON

The food-soup still contains many valuable components and it has one last stop: the colon, also called the large intestine. These nutrients are usually parts of plant-based foods that are resistant to digestion by enzymes, and they are called dietary fiber. Dietary fiber can only be broken down when it meets the broad variety of helpful bacteria that live in the large intestine. These bacteria are called the **microbiota**.

MICROBIOTA

A broad variety of helpful bacteria that live in the large intestine.

When the microbiota breaks down the fibers in the food soup, they make important substances such as vitamins and other nutrients. These are the final nutrients that are absorbed from our foods. In addition to helping us to digest food, the microbiota also trains the immune system, protecting us from infections, and it helps to regulate appetite [5]. The microbiota can even influence whether we feel happy or sad! So, it helps when foods have more structure and a tough matrix, to ensure the microbiota receives these important materials so the bacteria can complete their important work.

At the end of the colon, waste (poo) is produced. Poo contains the undigested nutrients, water, and cells (from the microbiota and from the intestinal wall). The dietary fibers in your food have most influence on poo composition and quantity. The colon can also suck water back up into the body, to ensure you do not dehydrate. This process determines how solid your poop is. If too little water is re-absorbed, your poo is more watery, or even diarrhea. Have you ever wondered about the color of poo? This is not so much determined by what you eat, but by brown and yellow substances produced by the digestive system. Some colored compounds from our foods can also make it to the colon undigested and color your poo, like beetroots or blueberries.

TAKE-HOME MESSAGES

The different stages of the digestive system have specific jobs in breaking down food and absorbing nutrients. In the mouth, food is broken into smaller pieces. In the stomach, the food is further broken up into nutrients. In the small and large intestines, nutrients are absorbed into the blood. Only the undigestible material from food remains in the leftovers as poo! Foods with complex structures can influence how quickly or slowly food is broken down at all stages of the digestive tract, affecting how much you want to eat and how fast you get hungry again. With modern food technology, we can use these food structures to target the delivery of specific nutrients to different parts of the digestive tract, to keep the gut microbiota happy. Sensors in the digestive tract communicate with the brain, signaling the arrival of nutrients. This is how the body knows what is coming and how to adapt our eating behaviors to regulate whether we feel hungry or full. Without us having to think about it, our bodies know how to best break foods down into their nutrient building blocks, getting the most out of the foods we eat!

REFERENCES

1. Forde, C. G., and Bolhuis, D. 2022. Interrelations between food form, texture, and matrix influence energy intake and metabolic responses. *Curr. Nutr. Rep.* 11:124–132. doi: 10.1007/s13668-022-00413-4

2. Goyal, R. K., Guo, Y., and Mashimo, H. 2019. Advances in the physiology of gastric emptying. *Neurogastroenterol. Motil.* 31:e13546. doi: 10.1111/nmo.13546
3. Capuano, E., and Janssen, A. E. M. 2021. Food matrix and macronutrient digestion. *Annu. Rev. Food Sci. Technol.* 12:193–212. doi: 10.1146/annurev-food-032519-051646
4. Corstens, M. N., Berton-Carabin, C. C., de Vries, R., Troost, F. J., Masclee, A. A., and Schroën, K. 2017. Food-grade micro-encapsulation systems that may induce satiety via delayed lipolysis: a review. *Crit. Rev. Food Sci. Nutr.* 57:2218–2244. doi: 10.1080/10408398.2015.1057634
5. Barber, T. M., Kabisch, S., Andreas F. H., Pfeiffer, A. F. H., and Weickert, M. O. 2020. The health benefits of dietary fibre. *Nutrients* 12:3209. doi: 10.3390/nu12103209

SUBMITTED: 14 February 2024; **ACCEPTED:** 25 June 2024;
PUBLISHED ONLINE: 08 July 2024.

EDITOR: Eesin Chen, National University of Singapore, Singapore

SCIENCE MENTORS: Theju Jacob, Kawaljit Kaur, and Linda Yip

CITATION: Corstens MN and Forde C (2024) From Chew to Poo—How a Food's Structure Changes Digestion. Front. Young Minds 12:1386116. doi: 10.3389/frym.2024.1386116

CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

COPYRIGHT © 2024 Corstens and Forde. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.

YOUNG REVIEWERS

ARMAAN, AGE: 12

I am passionate about drawing, reading, and writing. Currently, I am working on a book entitled "Divine Passage: New Beginnings". It is about a boy named Armaan (Wonder why that is his name) who goes on meeting gods and facing challenges. I get my drawing inspiration from Pokémon lore (My drawings feature Pokémon and Pokémon fusions), and reading. Where do I even begin? To start it off, I love to read mythology but also informational books. Not to mention, I also love baking.

ELIZABETH, AGE: 12

My name is Elizabeth, and my interests are in science in general, mainly environmental sciences. I want to find uses for the waste that we produce and focus on renewable energy solutions as energy will become a problem when our population grows. I like cats and trees and recycling bins and enjoy reading books.

LAUREN, AGE: 12

I am 12 years old and have a deep interest in science, especially physics, biology, and mycology. My hobbies include track and field, writing, reading, and chess. I also enjoy programming, geography, exploring new places, and growing my own mushrooms. I live with my parents, my little sister and my 2 cats.

WARIS, AGE: 9

My name is Waris and I am 9 years old. I have hobbies in coding games, building structures, and playing video games. I also excel in studies such as math, science, history, and reading. Just note that this is a brief recap of me.

AUTHORS

MEINOU N. CORSTENS

I have always been fascinated by the role of food in human health, which led me to study both nutrition & health and food technology and become an assistant professor in food process engineering (Wageningen University, the Netherlands). It is my ambition to contribute to the knowledge needed to design healthier foods. I greatly enjoy sharing science with kids (including my own 2 sons!) and teens around the world! In my picture, you can see me at the Science is Wonderful fair in Brussels!
*meinou.corstens@wur.nl

CIARÁN FORDE

I am originally from Ireland and am a professor of sensory science and eating behavior at the Division of Human Nutrition in Wageningen University, the Netherlands. I love food, and study food science and nutrition to better understand how we choose and consume foods. I want to understand how we can make foods healthier and improve diets using a better understanding of food structure, digestion, and human eating behavior. In my spare time, I love to cook Korean food and spend time with my wife and 4 daughters.