

Myths and truths about rice digestion and its impact on rice processing and consumption

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The main reason to study the various factors that interfere during the oral, gastric and small intestinal digestion of rice is very simple i.e. consumer health. The digestibility of rice components, mainly carbohydrates has received much attention because of its contribution towards obesity, which also leads to the metabolic syndrome, and is generally characterized by glucose intolerance. Knowing the rate of digestion is of utmost importance, mainly to identify how constant is the glucose release during continued digestion and absorption in the small intestine and, consequently, how it contributes for the urge to eat again. When it comes to rice, several factors may influence the digestibility, among which chewing, processing, degree of cooking, type of rice and the amylose content may be prominent; and the most economical way to identify these factors is by using *in vitro* oral-, gastro-small intestinal digestion models to study starch digestibility. These points will be detailed throughout the article.

In vitro digestion

In vitro digestion aims to simulate the digestive process of humans (Figure 1). However, digestion in humans is very complex, so perfect simulations are not possible yet. The enzymes present in the human body are difficult to extract and / or present high cost, therefore other mammalian enzymes, for example, pepsin and pancreatin obtained from porcine pancreas or microorganisms are commonly used in *in vitro* systems.

The *in vitro* system commonly used to study starch digestion in the laboratory is based on simulating the conditions of the oral (mouth), stomach and small intestine using digestion fluids. The curve obtained (Figure 2) from *in vitro* gastro-small intestinal digestion represents how much glucose was released during gastric (stomach G0, G15 and G30 at times 0, 15 and 30 min of digestion) and during small intestinal digestion (I0, I5, I10, I20, I30, I60 and I90 at times 0, 5, 10, 20, 30, 60 and 90 min).

Eventhough *in vitro* digestion is a highly useful technique but there are some limitations such as that it is not possible to exactly simulate the whole physiology of the human body which may influence the rate of starch digestion; however, when a methodology is standardized it is possible to compare samples more accurately, since *in vivo* digestion (using animals) changes can occur from individual to individual, resulting in large variations in the same sample.

Several scientific studies have found a good agreement among the *in vitro* and *in vivo* digestion results.

Factors that influence starch digestion of rice

Chewing

Generally, *in vitro* digestibility or starch digestion approach consists of a two steps digestion system simulating stomach and small intestinal conditions.

However, a very important step in the digestion process sometimes goes unnoticed: chewing. The oral digestion step has two simultaneous actions: chewing to provide mechanical milling and the enzymatic hydrolysis of the starch, which is mediated by saliva. After the food is crushed into small pieces and mixed with saliva mediated by chewing, the starch digesting amylase enzyme that is present in saliva is able to act on the starch in food.

Research has reported that the effect of salivary α -amylase on the simulated oral digestion step influences both the equilibrium percentage of the starch hydrolysis and the kinetic constant during the combined *in vitro* digestion process, concluding that this step may affect increases in postprandial blood glucose levels in humans.

“The fibers from brown rice serve as a barrier to the digestive enzymes and leads to reduced rates of starch hydrolysis, contributing to a reduced glucose response”

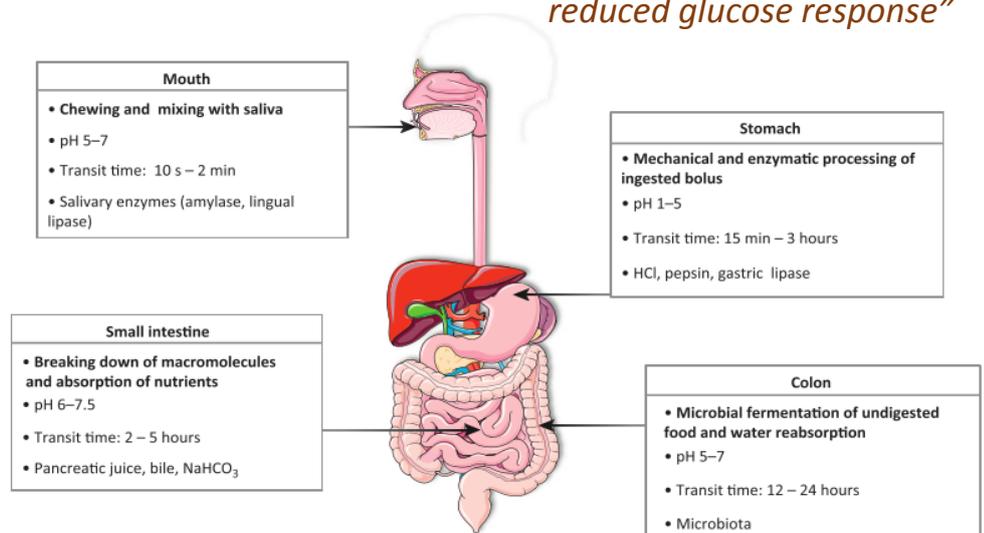


Figure 1. Region specificity of the human gastrointestinal tract. Adapted from Guerra et al. Trends in Biotech, 30(11), 591-600, 2012.

Degree of cooking

Generally, starchy foods, such as rice, are consumed after cooking or gelatinization, which results from the addition of water and heating for better digestibility of the starch. Some studies suggest that the consumption of raw or semi-cooked starch can be considered as a low GI food resource.

A study carried out in Japan reports the differences in digestibility kinetics of uncooked and cooked rice samples, where the structural characteristics of rice grains, including cell-scale structures, were observed and related to starch digestibility. The authors observed that rice digestibility was less affected by cooking degree (or starch gelatinization), but rather influenced by structural changes in grain due to mechanical processing, which may be related to chewing during the ingestion of cooked rice.

Amylose content

Many factors, including surface organization (pores, for example), granular architecture, starch composition, type of polymorphism, granular size and the presence of compound granules, have been reported to affect the rate of starch digestion.

The exact mechanism of the relative strength of starch granules is difficult to measure because these factors are often intertwined. In general, the digestibility in granular starches is positively correlated with the amylose level. The content of amylose therefore influences the textural characteristics of cooked rice and should be considered when selecting rice for specific applications.

In a study conducted in Canada, researchers compared the digestibility of rice by considering different levels of amylose in them and found that the with higher amylose content, is obtained the lower is the content of slowly digestible starch. This fact is mainly due to the higher gelatinization temperature of these grains and the consequent greater difficulty of water ingress during cooking. In addition, there is a greater complexation of amylose with lipids, which contributes to a lower impact on glycemia.

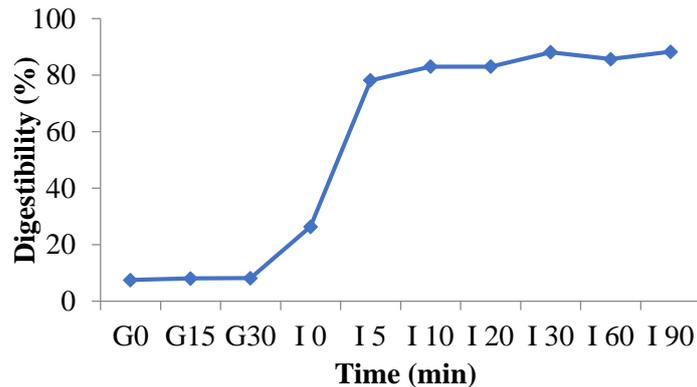


Figure 2. Example of curve obtained during *in vitro* digestibility analysis.

White rice x brown rice

Studies showed that brown rice generates a lower glycemic response than white rice. This effect is partially attributed to the higher amounts of polyphenols, phytic acid and oil present in brown rice in relation to white rice.

More importantly, it is the presence of the dietary fiber rich bran fraction present in brown rice, which may serve as a barrier to the action of digestive enzymes and leads to reduced rates of stomach emptying and starch hydrolysis, contributing to a reduced glucose response. On the other hand, studies show that when brown rice is ground, it is hydrolyzed at the same rate as white rice, despite the higher concentration of fiber, indicating that the physical form of the meal may play an important role in the regulation of postprandial glycemia.

In the literature it is possible to find several studies on rice digestibility, using *in vivo* and *in vitro* assays. *In vivo* studies have focused on the effect of rice on glucose and insulin response as well as chronic diseases such as diabetes. *In vitro* assays investigated the rate of starch digestion using pancreatic enzymes, emphasizing the role of dietary fiber.

For example, Leonora *et al.* (2006) tested the hydrolysis of starch in rice and found that the total sugar liberated by brown rice was 23.7% lower than in white rice. Kong *et al.* (2011) have done a more in-depth study and reported that there are a number of factors that influence the lower digestibility of brown rice. They mention that the brown rice bran layer inhibits the diffusion of gastric juice during digestion, limiting acid hydrolysis, material leaching, and texture degradation.

Differently of white rice, in brown rice the hard bran layer resists disintegration, generating a larger particle size in the digesta by reducing the surface area that can reduce the rate of starch digestion. The large particle size and dietary fiber also promote increase in the digesta viscosity of brown rice. All of these effects may result in lower rate of stomach emptying and reduced glucose response with brown rice that is beneficial to human health.

Rice with colored pericarp

In Brazil the pigmented types of rice are still consumed by specific market niches, however, the increase in consumer interest in healthier foods and changes in their eating patterns have stimulated production, aiming to increase the availability of these grains for consumption.

The main health benefits attributed to pigmented rice are related to the presence of phenolic compounds. Phenolic compounds, in addition to their proven antioxidant capacity, have the ability to inhibit the activity of some enzymes such as α -glycosidase and amylases present in the small intestine necessary for the digestibility of carbohydrates.

Studies have indicated that carbohydrate digestibility of red rice is greater than that black rice, which was attributed to the presence of phenolic compounds. In the case of red and black rice, the potential health benefits can go far beyond phenolic compounds because of the high dietary fiber content that could help reduce the glycemic index and consequently reduce the risk of type II diabetes.

How digestibility can influence the rice processing and the consumer?

For the industry, complementary information can add value to the products. In Brazil, products with this information are not yet available, but in other countries this information is already a reality. An example of this is the “Doongara rice” (Figure 3).

This brand invested in digestibility information on the packaging, so that it describes in three different ways the same information: white rice with low glycemic index, helps you stay fuller for longer and sustained energy release.

In addition, information on the glycemic index, grain characteristics and taste can be found on the company's website. Certainly the consumer who has some kind of illness or a controlled diet would not mind paying a little more to know exactly what he is consuming.



Figure 3. Example of packaging with information about digestibility.

Market trends

We consumers are becoming more demanding, and the trend is that if the product has good quality, health benefits and additional information that catches the consumer's attention, they will not mind paying a little more for this. In addition, in search of a healthy life, the tendency is the increasing consumption of integral products, rice with colored pericarp, among others.

The consumption of pre-ready products also tends to increase, especially if it presents characteristics beneficial to the health of the consumer, easy handling and consumption.

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