

Physicochemical, sensory, and nutritional characteristics of parboiled rice

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The world has become highly susceptible to uncertain information about food. One of the reasons is the easy and questionable search of information through unknown websites. Recently, the research team from Labgrãos decided to ask rice consumers about what they known about parboiled rice. Results were scary.

The lack of dissemination of proper scientific information about parboiled rice maybe is one of the causes for its low consume compared to conventionally-industrialized rice.

The term “parboiling” comes from the junction of the english words “partial” and “boiling”. In sum, parboiled rice is the product that has been subjected to parboiling, which consists in the use of a hydrothermal process previously to dehusking and polishing steps. In some regions of Asia, brown rice is used for the hydrothermal treatment, but the use of paddy rice is the most common process.

The changes that occur in starch granules and proteins as rice absorbs water and is subjected to heating lead to the most striking paradox of the process: How parboiled rice, that is considered a pre-cooked product, takes more time for a full cooking?

Brazil has one of the most advanced parboiling technologies in the world and, to discuss the changes brought about in rice constituents during parboiling and the consequent changes in rice properties, it should be understood that the extent of these changes depends on parboiling processing conditions. The success of parboiling systems is determined by the quality of parboiled rice, measured by parameters such as head rice yield and degree of gelatinization.

In traditional parboiling process, rice can be soaked in water for long periods - from 12 to 48 h - or using shorter periods in modern processes, varying from 2 to 6 h. As the temperature increases from 25 to 80 °C, the soaking time decreases from 60 hours to 1.5 hour.

In order to improve the gelatinization efficiency of the starch granules, other processes have been developed. These include thermal fluid systems, conventional autoclaving (hot steam) and continuous-flow autoclaving.

Different methods of parboiling result in a wide range of product quality variation. The severity or intensity of parboiling exhibits a strong influence on the final product properties, which will be discussed in the following sections.

Physical changes

Rice grains are mainly constituted by starch granules which, in turn, are composed by two macromolecules: amylose and amylopectin. Amylose is an essentially linear molecule composed of glucose units linked by α -1,4-glycosidic linkages, with a small number of branch points, and amylopectin is formed by glucose units linked by both α -1,4 and α -1,6-glycosidic linkages, that provides a highly branched structure.

During grain maturation, some cracks and may be developed through intergranular spaces from endosperm, which may lead to grain breakage during subsequent processes of rice, mainly during the polishing step.

Parboiling promotes full or partial starch gelatinization. When gelatinized starch cool down, amylose macromolecules re-associate and the endosperm is restructured into a more compact matrix. Depending on the extent of gelatinization, different levels of amylose-amylose, amylose-amylopectin, amylose-lipid, and/or amylose-protein interactions may occur.

In general, gelatinization is less pronounced when the soaking step is performed using cold water since there is limited water absorption by starch granules. Soaking at high temperatures increases diffusion coefficients, which lead to increased hydration as well as reduced soaking duration, thus avoiding enzymatic reactions and microbial fermentation that could cause discoloration and unpleasant taste in parboiled rice.

Figure 1 exhibits the soaking behavior of a Brazilian rice genotype when subjected to the most applied soaking temperatures in Brazil: 60, 65, and 70 °C. In the presented example, the optimum rice moisture content of 30% was achieved when hydration was performed at 65 °C during 360 min. The following step is autoclaving (or pressure steaming), when starch will be fully or partially gelatinized.

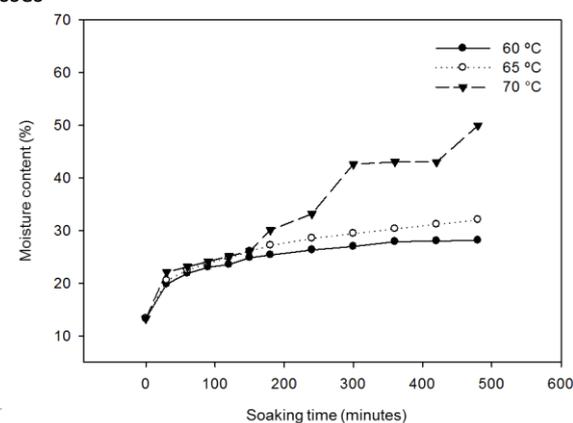


Figure 1. Soaking behavior of the rice cultivar Guri INTA CL at different temperatures.

Chemical changes

Starch granules play an essential role in the water absorption during cooking and exert a great influence on the quality of cooked rice. Parboiling changes starch arrangement from a semi-crystalline to an amorphous phase, due to its irreversible swelling and melting. Besides that, amylose-lipid complexes and the induction of new disulfide bonds between proteins may be formed, reducing starch and proteins extractability.

Rice glutelins distributed in the endosperm fraction of caryopsis act as a barrier to water penetration in both parboiled and non-parboiled rice. These proteins restrict the swelling of starch granules during thermal processing and may be strengthened after parboiling. Higher starch-starch, starch-protein, and protein-protein interactions may difficult the cooking process of rice.

In the hydrothermal treatment, the structure of the grain is altered, being more compact and vitreous (Figure 2). After parboiling, the chalkiness of rice is reduced, making rice translucent, thus contributing to increases in head rice yield, nutritional value of rice and its stability during storage.

During the pressure steaming step, enzymes naturally distributed in rice embryo, such as lipases and peroxidases, are inactivated, providing an increase in rice shelf-life. Subsequently, in the drying step, starch retrogradation is completed, which makes parboiled rice more resistant to the operations that use friction, such as polishing.

Another important chemical change that occurs in rice subjected to parboiling is associated to rice whiteness (Figure 3). In many countries, consumers requires parboiled rice with the most similar color to non-parboiled polished rice, as much as possible. However, some color changes occur during parboiling and the intensity of this alterations may be controlled by parboiling variables. During the soaking step, enzymes mainly concentrated in the aleurone layer and in the germ fractions are released. At a certain level, lipolytic enzymes may act on lipids. On the other hand, amylolytic enzymes will start acting on starch macromolecules, releasing sugars. Free amino acids and free sugar residues may favor the occurrence of Maillard reaction.

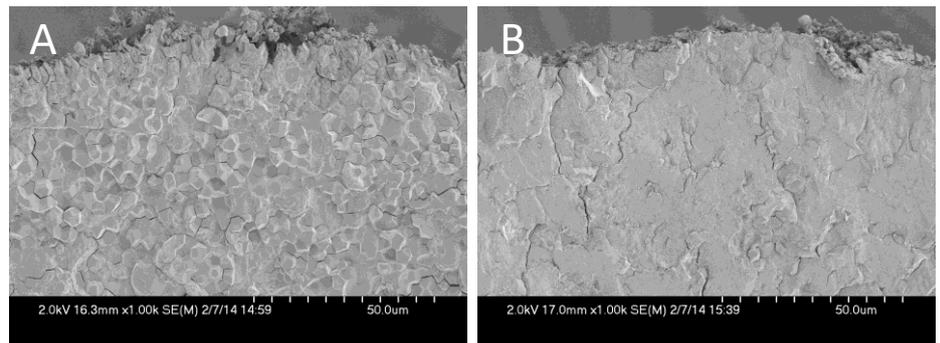


Figure 2. Scanning electron micrographs of endosperm cross-sections of non-parboiled polished rice (a) and parboiled polished rice (b). Non-parboiled rice exhibits a weak matrix, where starch granules are well-perceived as polyhedral granules with rice glutelins surrounding this starchy matrix. Parboiled rice exhibits a compact and vitreous structure, where starch granules have lost their semi-crystalline structure.

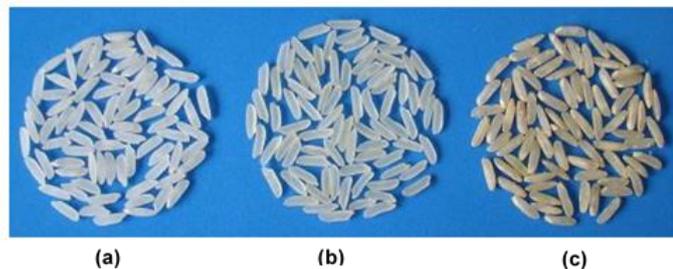


Figure 3. Polished white rice (a), parboiled polished (b) and brown rice (c). Source: Epagri, 2016.

The reducing sugars released when starch macromolecules are cleaved by amylases can react with free amino acids, triggering Maillard reactions. This is a type of non-enzymatic browning that occur in rice during parboiling. In general, temperatures may be higher than 60 °C for this kind of reactions.

Sensory changes and nutritional value

Parboiled rice exhibits typical sensory attributes that distinguish it from brown and polished rice. In most cases, the characteristic sensory attributes are responsible for the reduced acceptability of parboiled rice by consumers. This include the stronger taste, aroma, and the dark coloration of parboiled rice. These characteristics should be minimized, as far as possible, in order to broaden its use to other markets and to obtain greater consumers' acceptability.

On the other hand, one fact favors the market opportunities for parboiled rice: it has been an increase in the percentage of consumers looking for nutritionally-improved products, that meets "food & healthiness" requirements.

Some water soluble compounds may be transported from bran layers to the inner endosperm fraction of rice during soaking step, increasing the nutritional value of polished rice. The pressure steaming step promotes the intensification of the dark color in rice.

Parboiled rice generally presents higher volumetric and gravimetric yield after cooking, and requires less oil for cooking considering the traditional cooking procedure performed by Brazilians. Also, parboiled rice is more prone to be reheated more than twice and maintain its nutritional properties.

“Some color changes occur during parboiling and the intensity of this alterations may be controlled by parboiling variables”

Interference of parboiling variables on rice quality

The changes that parboiling causes in rice are closely linked to the intensity of the processing conditions employed. When processing conditions are not properly set up, several problems may arise: (a) fermentation of paddy rice during or after soaking; (b) low degree of gelatinization; (c) low head rice yield due to incorrect drying procedure; (d) high darkening level; and (e) strong flavor and aroma in the final product.

The degree of gelatinization of starch is one of the main factors associated to the quality of parboiled rice. Proper gelatinization makes the grain harder, improving its polishing quality. Incomplete gelatinization results in white core grains, while the fully gelatinized endosperm becomes translucent (Figure 4). The moisture content, the steaming time and temperature, and the rice composition influence the gelatinization extent of starch.

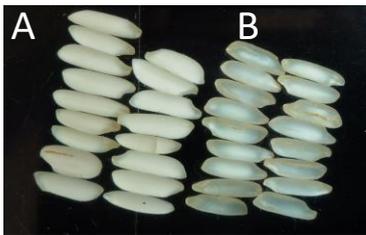


Figure 4. Opaque non-parboiled (A) and translucent well-parboiled (B) rice. The existence of some opaque areas in parboiled rice indicates the gelatinization extent of rice.

The extent of browning has also been improved by reducing the soaking time. About 45 minutes of watering at 80 °C followed by autoclaving for 10 minutes at atmospheric pressure have been shown as sufficient for improving the quality of rice, and, consequently, increasing consumers' acceptability.

As an alternative for reducing browning intensity in parboiled rice, some anti-browning agents have been tested at Labgrãos. Successful results were achieved by adding glycine to the soaking water at levels varying from 0.1% to 0.5%. Moreover, reduced glutathione can also be used, but at higher levels, varying from 1.0% to 2.0%.

The presence of amylose crystallites in parboiled rice has been determined in research by X-ray diffractograms analysis. Results from studies conducted at Labgrãos showed that this type of complex is dependent on parboiling conditions and free amylose content. The formation of heat stable amylose-lipid complexes is favored by severe parboiling conditions.

Processing variables to be adjusted as a function of rice characteristics include (a) soaking time, (b) soaking water temperature, (c) pressure to be used during pressure steaming treatment, (d) time of autoclaving, (e) drying conditions prior dehusking, and (f) tempering time and temperature.

The increase in hybrid cultivars production requires the attention of rice parboiling industries, since, in sum, the parboiling set up for those cultivars is different than parboiling conditions applied to pure lines.

Studies conducted at Department of Food Science from University of Arkansas, coordinated by Dr. Ya-Jane Wang, showed that the head rice yield (HRY) of parboiled rice is strongly affected by the soaking temperature. Moreover, the use of commingled rice was proved to be prejudicial for the industrial quality of rice. The autoclaving time is the most influential factor in the degree of starch gelatinization, interfering with the incidence of white core grains, deformed grains and paste viscosity. Greater pressure steaming periods provides rice with greater degree of gelatinization.



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