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Review

Parboiled rice: Understanding from a materials science approach

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ABSTRACT

The material properties like glass transition temperature, diffusion, microstructures of rice kernels and gelatinisation and retrogradation of the rice starch are reviewed to understand the nature and quality of the parboiled rice. Details of the diffusion related material properties of rice kernels such as the rate of diffusion, different models of diffusion, diffusion in glassy and rubbery state and diffusion in the gelatinised starch are discussed. The influences of hydrothermal treatment on the properties of the rice kernel are also highlighted to understand the overall quality of parboiled rice.

Contents

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1. Introduction

Rice (*Oryza sativa* L.) is an important staple food for nearly one-half of the world's population, contributing 21% of the global human per capita energy and 15% of per capita protein. More than a billion households of Asia, Africa and South America are dependent on rice for their main source of income and employment. Rice fields cover more than 9% of total earth's arable land (Maclean et al., 2002).

The forms that rice is consumed include whole grains (brown, milled or parboiled), flour and fermented products. Parboiled rice is prepared by soaking, cooking and drying of paddy (or brown rice) before milling.

The preference for parboiled over milled rice is based on the 'traditional taste' preference of consumers, with some areas in South Asia preferring parboiled rice because it is typically less sticky than non-parboiled rice (Kato et al., 1983; Unnikrishnan and Bhattacharya, 1987). In addition, it is also preferred by health sensitive consumers due to its better nutritional properties compared to non-parboiled rice. Agronomic conditions during harvesting also promote the need to parboil rice because almost all the rice harvested during rainy season and rice that has experienced flooding during harvesting show excesssive breakage during milling (Bhattacharya, 2011). To counteract this, the paddy is parboiled to improve the Head Rice Yield (HRY).

The type of rice chosen (e.g. amylose content and grain length) and parboiling method varies between countries and depending on its intended final use (Juliano, 1993). This literature review aims to provide a critical assessment of research behind the physical and chemical processes that impact on grain quality to better understand the choice of variety and methods used.

2. Parboiling processes

There are many variations in traditional methods of parboiling depending on the place and scale of operation (Araullo et al., 1976), but the basic production steps are hydration of the paddy (to a moisture level ~24–30% wb), thermal treatment to achieve complete gelatinisation and dehydration to a moisture content appropriate for milling. In large scale commercial parboiling processes, variation in the processes is done to make it efficient, economical and to improve the end product quality (Bhattacharya, 2004).

Different variations of the parboiling process yield rice with different material properties, and so may challenge consumer preference for the product. For example, the hot soaking process gives a more discoloured product than cold soaking process, while pressure parboiled rice is even more discoloured. Furthermore, the cold water soaking method taints the paddy with off flavours. The dry parboiled rice has the faster dehydration and puffing charactreristics than others. A brief comparison of commercial parboiling processes is given in Table 1.

In addition to the more common parboiling processes, there are other methods such as combination soaking (Igathinathane et al., 2005), ultrasonic soaking (Wambura et al., 2008), and soaking in alkali or acid solutions (Bello et al., 2004) but these are not widely used.

3. Diffusion, gelatinisation and retrogradation in parboiled rice

The key factors in controlling the material change due to changes in chemical and physical properties of the rice grain during parboiling process are:

- Diffusion of water and other compounds into and out of the rice grain during hydration (rice soaking), dehydration (drying) and re-hydration (cooking prior to consumption).
- Starch gelatinisation and protein denaturation during heating as affected by moisture content, temperature and time.
- Starch retrogradation after heat treatment process.

Here, a review of the phenomena encountered, and the opportunities that exist to tailor the final quality of parboiled rice to consumer demand will be presented.

3.1. Diffusion

Diffusion is common to all steps of parboiling. The diffusion properties of rice depend on a number of factors including grain structure, composition, post-harvest processing, temperature and moisture content. The following section will examine how rice grain structure, microstructure, composition and glass transition dictate diffusion during hydration and dehydration processes.

3.1.1. Glass transition and diffusivity

Starch below the glass transition temperature (T_g) is in glassy state with low expansion coefficients, specific volume and diffusivity. In comparison, starch above the T_g is rubbery with a higher expansion coefficient, specific volume and diffusivity. This physical change is influenced by the moisture content of the grain, with increased moisture content decreasing the glass transition temperature (Perdon et al., 2000; Slade and Levine, 1995; Slade et al., 1991). The glass transition that starch undergoes during drying plays an important role in determining the Head Rice Yield (HRY) (Ondier et al., 2012; Perdon et al., 2000). It has been reported that the annealing of starch that happens above glass transition also reduces the kernel breakage (Truong et al., 2012).

During soaking, the hydration rate increases with an increase in soak water temperature. When the temperature exceeds the gelatinisation temperature, the water absorption increases significantly (Bakshi and Singh, 1980; Bello et al., 2007; Suzuki et al., 1977). This phenomenon may also be true for other water soluble components such as inward and outward diffusion of pigments and micronutrients. The glass transition temperature of parboiled paddy is around 20 °C (Siebenmorgen et al., 2004), or even lower due to the thermal breakdown of starch into lower molecular weight compounds (Fery, 1980; Slade and Levine, 1995). Drying of parboiled paddy above its T_g would be faster because it would have the starch with greater free volume where the water is more mobile (Slade et al., 1991) creating the higher diffusion rate.