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Steps of Parboiling Cooked Grain and Their Properties

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Abstract

Paddy grain is a multi-layered material consisting of husk, bran and starch. These three different layers have different material properties and hence differ in the rate of water diffusion. The characteristics of the husk may be important factors in water diffusivity.

Keywords: Coefficient; Inter-locking; Maturity; Transition; Hydration; Lipids

Introduction

An earlier study suggested that if the husk of the paddy could be slightly opened, the diffusion rate would be much faster than the paddy with intact husk. The water diffusion coefficient of the de-husked brown rice is at least two times greater than that of paddy which suggests that the husk as one of the major barrier for water diffusion . However, the diffusion coefficient also varies depending on the temperature and variety. Some paddy varieties have hairy husks and awn which further impose a barrier for diffusion. The varieties that have tighter inter-locking between lemma and plea are more resistant to hydration than the varieties that have loose interlocking. Additionally, the hydration of rice grain can be affected by its position in the panicle. The grains in the primary panicles as well as those in the top of the panicles attained complete hydration faster than the grains in lower positions [1]. This was found to be a result of variation in the material properties among the grains within the same panicle due to their relative maturity. Absorbs less water than milled rice during cooking. This has been attributed to the bran which is composed of hydrophobic waxy cuticle high in lipid content that offers the physical barrier for water diffusion into the kernel. The bran is also rich in protein and this also limits the starch hydration. In totality, the bran cuticle containing the high surface lipids and surface proteins collectively act as the barrier to diffusion [2]. The microstructure of the rice kernel such as the granular arrangements of starch pores and cracks present in the endosperm affect the diffusion process. The water diffusion in a polymeric system is related to the availability of molecular-sized holes in the polymer structure and polymer–water affinity. The number of holes depends on the microstructure of starch polymer, its morphology and crosslink density.

Discussion

In addition to pores, rice kernels have cracks in the kernel that also contribute to the free volume in the kernel. The cracks are created due to the moisture stress during pre-harvest or post-harvest stage. Together; these pores and cracks act as the water channels which affect the rate of diffusion. For many polymer systems, the free volume created within the materials tends to dominate the diffusion process because the change in volume of the polymer due to moisture induced swelling is significantly less than the volume of moisture absorbed. This indicates that a large portion of the absorbed water resides in the free volume created by the pores and cracks. In rice kernels, the true density of the kernel increased with the increase in soaking temperature up to 40 °C but it decreased when the soaking temperature was 70°C. It can be inferred from this result that the true density of kernel increases below the gelatinisation temperature because it gains mass but does not expand much in volume [3]. During hydration of a polymer in the glassy phase, the water first fills the pores and cracks before causing an expansion in kernel volume. A larger number of pores and cracks will facilitate the higher water mass diffusion. When the temperature passes the glass transition temperature, the starch granules swell and the volume increases significantly than the mass thereby decreasing the kernel density. Hence, it can be said that for the starch polymer in rice also, the free volume present due to the cracks and microstructure of the starch plays a dominant role in water diffusion before starch gelatinisation occurs. Lipids in rice are classified into two types: non-starch and starch lipids. Rice bran is mainly composed of the aleurone layer and embryo, and contains 60% of non-starch lipids that are the major lipids present in bran layer as spherosomes [4]. Starch lipids are present at relatively low concentrations and primarily in complex with amylose. Non-waxy rice, having a higher content of amylose, contains more starch lipids and less non-starch lipids than waxy milled rice. The hydrophobic nature of lipids offers a barrier for the mass water diffusion. The hydration of brown rice was much slower than the milled rice did a study on cereal bran and found that the defatted bran had higher water absorption than full fat bran. They reasoned that the hydrophobic nature of fat, which might have contributed to the reduced water absorption of full-fat bran, while the hydrophilic nature of crude fibre might have contributed to the increased water absorption in the defatted bran samples. Confirmation of this could be achieved if an appropriate method for lipid removal from whole kernel without affecting its composition and micro-structure could be developed. Proteins are most concentrated on the outer surface of rice kernel and in the bran. Surface proteins may have the role in regulating the water diffusion into the starch granule and control the granule swelling during gelatinisation because glass transition of protein is slightly lower than that of starch and hence it will have higher water absorption capacity than starch [5]. Despite their presence at a lower concentration than starch in the rice, proteins have been identified as the major water absorbers. It has been reported that high protein rice requires more water and longer time to cook. The faster hydration of

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protein than starch leads to the general conclusion that protein has a higher water diffusion coefficient than starch. Starch has a multi-scale structural model where the granules are made from the alternating growth rings of amorphous and crystalline structure. This gives three different dynamic components in the starch, namely a highly crystalline region formed from amylopectin double helices; a more mobile, rubber-like amorphous region associated with amylopectin branch points and solid-like regions formed from lipid inclusion complexes of amylose. However, the distinction between crystalline and amorphous states in starch is not absolutely clear in terms of molecular order [6]. Starch granules contain pores on the surface that extend to the centre of the granules. Based on the X-ray diffraction pattern, native rice starch is classified as type A-crystalline. These types of structures are closely packed with water molecules between each double helical structure, whereas B-types are more open and water molecules are located in the central cavity. Four water reservoirs in the potato starch which were extra-granular water, water in the amorphous growth rings, water in the semi-crystalline lamellae and channel water located in the hexagonal pores of amylopectin crystals. However, they did not find the ‘‘channel water’’ in A-type crystals that are prevalent in non-parboiled rice starch. The amorphous regions of starch are considered to be susceptible to chemical reaction because this region swells the most upon hydration. The distribution of crystalline and amorphous regions of starch could be the determining factor for water diffusion within the starch granules. The crystallinity of the rice starch is greatly influenced by the moisture content and the amylopectin content. But amylose content has little effect on crystallinity for A-type starches [7]. The higher gelatinisation temperature for the increasing level of crystallinity suggests that less water diffusion and swelling occurs in such rice kernels. The final stage of the parboiling process after the starch in kernel is gelatinised during the soaking and heating steps of parboiling, is to dry the kernel to a safe moisture level in order to render it suitable for further processing or storage conditions [8]. The drying pattern of the kernels that has gelatinised starch will be different from the non-gelatinised counterpart because of the change in material properties. Gelatinised starch is irreversibly swollen whereby water occupies the internal kernel void spaces including channels and bound to starch chains. Upon drying at a fast rate, the vacated water leaves behind fissures and hollow cavities in the dried grain that further increase diffusivity to yield a low Head Rice Yield. Therefore to maintain and preferably improve Head Rice Yield, the final drying step of parboiling is crucial. At a molecular level, relative to unprocessed rice, during the final cooling and drying steps of parboiling the starch increases in crystallinity including the formation of crystalline amylose lipid complexes [9]. These changes to crystallinity are accompanied by a gradual change from a viscous amorphous state to a glassy state. The change in physical state in turn impacts the diffusion of water out of rice kernel. An uncooked rice grain absorbs less water than a parboiled rice grain at the room temperature. At temperatures near to the gelatinisation temperature of the rice, the uncooked rice grain absorbs more water than the parboiled rice. This unusual property of the hydration of the rice kernel has been explained from the viewpoint that water diffusion property of the starch is governed by the extent of starch gelatinisation and retrogradation, as well as the level of pores and fissures present in the grain [10].

Conclusion

However, a study on the rehydration of freeze dried parboiled rice showed that a higher extent of gelatinisation increased the rate of rehydration. This suggests that not only the extent of starch gelatinisation but the microstructure that underlines the gelatinised nature of the kernel affects the rehydration phenomena of par-boiled rice.

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Conflict of Interest

None

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