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Colour change in rice during hydration: Effect of hull and bran layers

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ABSTRACT

The colour change (yellowing or reddening) that occurs during parboiling affects the consumer acceptance of parboiled rice. In order to understand the factors controlling colour change in rice during hydration, trials were performed that examined the effect of variety (four commercial varieties: Kyeema, Langi, Reiziq[P] and Sherpa[P]), milling properties (Sherpa[P] High Head Rice Yield and Sherpa[P] Low Head Rice Yield), degree of processing before hydration (paddy, brown rice, milled rice) and hydration temperature (below and above gelatinisation temperature: 60 °C and 90 °C respectively). The total colour difference (ΔE_{00}) was calculated and four different models (zero order, first order, fractional and Page) were evaluated in order to predict the ΔE_{00}. The Page model was found to be the best model for predicting ΔE_{00}. There was no difference in ΔE_{00} between the breakage resistant and breakage prone grains however the varietal effect was observed. The degree of processing of rice before hydration affected the total colour change where the brown rice had the highest ΔE_{00} followed by paddy and milled rice.

1. Introduction

Rice colour is determined by a combination of genetic, agronomic and post-harvest factors (Ambardekar and Siebenmorgen, 2012; Belefant-Miller, 2009; Finocchiaro et al., 2010; Lanning and Siebenmorgen, 2013; Phillips et al., 1989; Phillips, et al., 1988). Common post-harvest processes, such as storage, drying or parboiling cause yellowing or reddening of the rice grain (Bhattacharya, 2004; Dillahunty et al., 2001; Siebenmorgen and Meullenet, 2004), though the conditions (e.g. time, temperature, water content) encountered differ widely between these processes.

Parboiling of paddy is a hydrothermal treatment normally performed prior to dehulling and milling. The resultant milled parboiled rice has a yellow colour while its non-parboiled counterpart is white. It has been proposed that the diffusion of bran and hull pigments, and enzymatic and non-enzymatic browning (Bhattacharya and Subba Rao, 1966; Lamberts et al., 2006b; Lamberts et al., 2008; Luh and Mickus, 1991) are the major causes of colour change in parboiled rice. In addition, the changes in starch morphology due to gelatinisation and retrogradation, and change in protein structure brought about by hydrothermal treatment may also affect colour change (Oli et al., 2014b).

There are a number of possible compounds such as phenolic acids and carotenoids associated with hull and bran layer of rice that could contribute to colour change in parboiled rice. The paddy hull is rich in phenolic acids (ferulic, chlorogenic and p-coumaric acids) (Butsat and Siriamornpun, 2010) which may diffuse into endosperm during parboiling process. Hence paddy that has a darker hull colour has been reported to give the darker coloured parboiled rice (Luh and Mickus, 1991).

The bran layer, in common with the hull layer, also contains phenolic acids and in addition contains a number of carotenoids (β-carotene, lutein, lycopene and zeaxanthin) that are yellow or red in colour (Abdul-Hamid et al., 2007; Frei and Becker, 2005; Lamberts and Delcour, 2008; Tan et al., 2005). The contribution of carotenoids to colour change during the parboiling of paddy or brown rice may be limited as it was found that they are leached out in to the soaking water, degraded or oxidized during the parboiling process (Lamberts and Delcour, 2008). However, parboiled rice produced from brown rice was reported to have increased redness (Lamberts and Delcour, 2008) suggesting that other bran pigments such as phenolic acids, may be responsible for the colour change. Phenolic

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acids were also found to be the major cause of colour change in barley flour (Quinde-Axtell and Baik, 2006). The predominant phenolic acids in rice hull and bran layers are ferulic, chlorogenic and p-coumaric acids which are also reported to be present in higher concentration in rice varieties with dark coloured bran (Shen et al., 2009). Parboiled rice has a higher concentration of total phenolics than non-parboiled rice (Finamor et al., 2012). Phenolic compounds need to be oxidized to impart the colour, however enzymatic oxidation of polyphenols was found to be insignificant during hydration process of rice (Lamberts et al., 2006a), suggesting that other factors promote oxidation such as the level of dissolved oxygen and temperature of hydrating water.

Non-enzymatic browning reactions such as caramelisation or Maillard browning induced by the heat-moisture treatment have been reported to contribute to the colour change in parboiled rice. For example, the formation of furosine, a Maillard reaction product, was reported to increase with increasing severity of hydrothermal treatment, which is consistent with reports that Maillard browning mainly occurs during the steaming step of parboiling (Lamberts et al., 2006a).

Thus, to understand the relative significance of colour change in rice during parboiling, the role of individual layers must be considered because in one hand these are the source of pigments whereas on the other hand they may be barriers to the diffusion process.

In this context, a study that compares colour change in hydrothermally treated rice with different layers can appropriately discern whether it is hull or bran or both are responsible for discolouration. Further, studying the changes during parboiling of milled rice will reveal whether colour changes are due to heat induced reactions such as Maillard browning. Similarly, the contribution of any microfissures present in the breakage-prone rice grains in colour change would give the information on the contribution of such diffusion-aiding structures. In addition, varietal effect and hydration temperature below and above the gelatinization temperature will enable us to understand the colour diffusion phenomena in greater detail. Hence, this study focuses on the colour change in different forms of paddy among the different varieties with differing milling characteristics during hydration below and above the gelatinisation temperature.

Previous studies of colour change in rice were based on the CIELAB method. This method provides the calculation of colour differences as vector distances which is not a suitable way of describing small differences in colour (Luo et al., 2001). Also the CIELAB method does not include any corrective parameters to allow for external observing conditions which may change the perceived magnitude of the colour difference (Sharma et al., 2005). To overcome the non-uniformity of the CIELAB colour space for small colour differences we will use the CIEDE2000 method recommended by CIE (2004). This improved approach adjusts the total colour difference evaluation by correcting the effects of lightness dependence, chroma dependence, hue dependence and hue–chroma interaction of the test sample.

2. Material and methods

2.1. Materials

Four different paddy varieties (Kyeema, Langi, Reiziq^P and Sherpa^P) harvested in 2012 and 2013 were obtained from the SunRice Appraisals Laboratory (NSW, Australia). Reiziq^P and Sherpa^P are protected by Intellectual Property Rights under the Plant Breeders Rights (PBR) Australia (Lewin et al., 2006; Reinke and Snell, 2011), and hence bear the PBR logo (P) as a superscript. The samples were packed in plastic bags and stored at 4 °C until required. Before conducting the experiments samples were taken out of the cool room and kept for 72 h at room temperature.

2.2. Methods

2.2.1. Grain physical characteristics

The length, width and thickness of the paddy, brown rice and milled rice samples were measured on 100 randomly selected grains using digital micrometer (InTech Electronics, VIC, Australia) at ±0.01 mm accuracy.

2.2.2. Amylose content

Amylose content was determined using the method described in AACC International Method number 61.03.01 (AACC International, 2011).

2.2.3. Protein

The protein content (N × 5.95) of rice flour was determined in duplicate by the combustion method using a LECO (model FP-2000) nitrogen analyser where the N content in the combustion gas was measured by calibrated Near Infra-red Analyser (AACC International, 2011).

2.2.4. Gelatinisation temperature

Milled rice grains were ground in a Cyclotec cyclone mill to pass through a 0.5 mm mesh. The ground samples (5 mg, db) were accurately weighed into the aluminium sample pans where accurately weighed deionised water (10 μL) was added to it. The sample pans were hermetically sealed and kept at least 1 h at room temperature to equilibrate. DSC measurements were done in Toledo DSC 822e with the heating rate of 10 °C per minute. The temperature corresponding to the peak of the endotherm was recognized as gelatinisation temperature.

2.2.5. Treatment of samples

The hydration treatment of the paddy, brown rice and milled rice was carried out at two different temperatures which were selected to cover the temperature range above and below the gelatinisation temperature of the samples.

Paddy (150 g), brown rice (100 g) and milled rice (100 g) were placed in flexible bags (FoodSaver, Sunbeam Australia; polyethylene/nylon laminate) and 500 mL of water pre-heated to the hydration temperature was added in each bags. The bags were sealed (model 4300, FoodSaver, Sunbeam, NSW, Australia) and immediately placed into temperature regulated water baths that were pre-heated to the hydration temperature (60 °C or 90 °C). After the pre-determined hydration time, the bags were removed from the water bath, opened, and liquid drained with a strainer. The hydrated samples were blotted with paper towels (4–5 times) to remove the surface water. The samples were then placed into plastic trays (120 mm × 120 mm) having screen (1.2 mm mesh) at the bottom and placed into the air dryer maintained at 40 ± 3 °C (relative humidity [RH] 24–40%). The choice of drying temperature of 40 °C was based on the fact that significant proportion of paddy is parboiled at homestead scale or in the small industry scale by drying in the sun around this temperature.

2.2.6. Milling

The paddy samples were dehulled in a laboratory dehuller (THU, Satake, Tokyo, Japan) and then milled for 60 s using a laboratory mill (McGill No. 2, RAPSCO, Brookshire, TX). Brown rice samples were also milled with same mill for 60 s.

2.2.7. Experimental design

There were two series of experiment. The first compared