Journal of Cereal Science 69 (2016) 267–274

Contents lists available at ScienceDirect

Journal of Cereal Science

journal homepage: www.elsevier.com/locate/jcs

Effect of soaking temperature on commingled rice properties

Kanokporn Leethanapanich [a], Andy Mauromoustakos [b], Ya-Jane Wang [a,*]

[a] Department of Food Science, University of Arkansas, 2650 N. Young Avenue, Fayetteville, AR 72704, USA
[b] Agricultural Statistics Laboratory, University of Arkansas, Fayetteville, AR 72701, USA

ARTICLE INFO

Article history:
Received 21 December 2015
Received in revised form
4 April 2016
Accepted 6 April 2016
Available online 7 April 2016

Keywords:
Commingled rice
Soaking temperature
Chalkiness
Head brown rice yield

ABSTRACT

Parboiling involves soaking, steaming, and drying, and soaking is important in achieving desired parboiled rice properties. This study investigated the effects of soaking temperature and commingling on rice properties prior to steaming. Rough rice of four cultivars (Taggart, CL151, XL753, and CL XL745) and their combinations at 1:1 wt ratio were soaked at 65, 70 or 75 °C for 3 h, and dried. Both soaking temperature and difference in onset gelatinization temperature (T_o) of individual cultivars in commingled rice affected milling and physicochemical properties. The head brown rice yield was greater when the soaking temperature was below but close to the T_o for individual rice cultivars, but became difficult to predict for commingled rice. Commingled rice consisting of high T_o rice cultivars required higher soaking temperatures to reduce chalkiness during soaking. The color attributes of commingled rice was predominately affected by the cultivar that exhibited the most change. The gelatinization properties were governed by the low-T_o cultivar, whereas the pasting properties were more influenced by the high-T_o cultivar for the commingled rice. Therefore, using commingled rice with a wide range of gelatinization temperature as a feedstock may lead to inconsistent quality of parboiled rice.

1. Introduction

Parboiled rice has been used in many applications such as canned rice, instant rice, ready-to-eat meals, and puffed cereals because of its ease of cooking and improved heat stability. Parboiling is a hydrothermal process involving soaking, steaming, and drying steps. Rough rice or brown rice is first soaked in excess water to become hydrated to allow starch gelatinization in the following steaming step. Drying is followed to dehydrate the rice kernels to approximately 12% moisture content (MC) for safe storage and good milling quality. The changes in rice properties after parboiling such as milling, physicochemical, cooking, and eating qualities are primarily attributed to the changes in starch as a result of gelatinization and retrogradation, although minor compositions like proteins and lipids also have influences on parboiled rice properties (Bhattacharya, 2004).

Soaking is an important step in the parboiling process. Rough rice is required to absorb water and reach equilibrium moisture content of approximately 30% for proper hydration (Gariboldi, 1974). The amount of absorbed water is dependent on soaking temperature and soaking duration. Bakshi and Singh (1980) reported that soaking at high temperatures increased diffusion coefficients, which leads to an increase in hydration as well as a reduction in soaking duration, thus preventing enzymatic reaction and microbial fermentation that could cause discoloration and off-flavor in parboiled rice. Bhattacharya and Subba Rao (1966) suggested that maximum milling yields and minimum breakages were obtained if rice kernels absorbed sufficient water during the soaking step. Chung et al. (1990) found an increase in head rice yield of parboiled rice with increasing soaking temperature of 50, 60, or 70 °C for 5, 4, or 3.5 h, respectively. Sareepuang et al. (2008) also observed the same trend when soaking rice at 40, 50, or 60 °C for 3 h.

Recently, the development of rice breeding program causes a drastic increase in the number of rice cultivars in the U.S., particularly hybrid cultivars. Studies have shown differences in milling characteristics between hybrid and pureline cultivars. Siebenmorgen et al. (2006) found that for the same milling duration, hybrids (XL7 and XL8) were milled to lower surface lipid contents than pureline cultivars (Cocodrie, Cypress, and Lemont), which was proposed to be due to a thinner bran layer in hybrid cultivars. Lanning and Siebenmorgen (2011) noted differences in

Abbreviations: T_o, onset gelatinization temperature; T_p, peak gelatinization temperature; T_c, conclusion gelatinization temperature; ΔH, enthalpy; MC, moisture content; RH, relative humidity; HBRY, head brown rice yield.

* Corresponding author.
E-mail address: yjwang@uark.edu (Y.-J. Wang).

http://dx.doi.org/10.1016/j.jcs.2016.04.002

milling characteristics between two pureline cultivars (Wells and Francis) and four hybrid cultivars (XL723, CL XL729, CL XL730, and CL XL745). Siebenmorgan et al. (2012) showed that hybrid cultivars required shorter milling durations than pureline cultivars to obtain the same degree of milling.

Basutkar et al. (2014) studied the effects of commingling (pureline/pureline, pureline/hybrid, and hybrid/hybrid) on milling properties of long-grain rice cultivars by mixing the rice cultivars into varying ratios (0:100, 10:90, 25:75, 50:50, 75:25, 90:10, and 100:0). They found that the milling duration to reach the same degree of milling (0.4% surface lipid content) for each commingled sample varied with the ratio of individual cultivar in a commingled sample. The whiteness and yellowness of milled rice were not significantly affected by commingling. Commingling, however, had an influence on the milled rice yield, head rice yield, and chalkiness, which could be predicted by calculating the weight average of the individual cultivar for each property. Basutkar et al. (2015) suggested that commingling of rice may cause inconsistent quality of products especially when there was a great difference in onset gelatinization temperature (T_o) of the rice cultivars in commingles. The T_o of commingled rice was governed by the rice cultivar with the lower T_o. The pasting viscosities of commingled rice changed proportionally according to the mass percentage of each cultivar in commingles.

It was hypothesized that using commingled rice with different T_o as a feedstock for parboiling may cause inconsistent quality of parboiled rice. Because soaking is the first step of parboiling where rice is subjected to heat, this study aimed at investigating the impacts of varying soaking temperatures on the milling and physiochemical properties of commingled rice.

2. Materials and methods

2.1. Materials

Rough rice of long-grain pureline (Taggart and CL151) and hybrid (CL XL745 and XL753) cultivars from the 2012 crop year were used in this study and obtained from the University of Arkansas Rice Processing Program (Fayetteville, AR). These cultivars were selected because they had the least and the greatest T_o among pureline and hybrid cultivars available from the 2012 crop year, as measured by a differential scanning calorimeter, of 72.1, 74.2, 73.3, and 78.1 °C for Taggart (T), CL151 (CL), CL XL745 (CLXL), and XL753 (XL), respectively. Six possible combinations of commingled rice samples were prepared using a 1:1 ratio based on rough rice weight (approximately at 12.5% MC). The rough rice was accurately weighed and mixed 5 times, 2 min each time, using a rotary rice grader (TRG, Satake, Tokyo, Japan). The 1:1 ratio of the individual rice cultivars was selected to prepare the comingled rice because it represents the most extreme situation that could result in the most impacts on rice properties when the two rice cultivars with the most difference in T_o according to Basutkar et al. (2014), in which the commingled rice properties such as peak viscosity increased or decreased proportionally according to the ratio of individual rice cultivars in commingles.

2.2. Soaking conditions

Soaking temperatures were chosen at 3–5 °C below T_o of individual and commingled rice samples. Rough rice (100 g) was soaked in 250 mL of deionized water in a water bath at 65°, 70°, or 75 °C for 3 h in order to reach a minimum 30% MC. The soaked rice was then dried at room temperature overnight and afterwards at an equilibrium moisture content (EMC) chamber at 26 °C and 65% RH for 2 days to reach ~12% MC.

2.3. Head brown rice yield

Dried rough rice was dehulled using a Satake THU-35 dehusker (THU-35, Satake Corp., Hiroshima, Japan). The broken brown rice kernels were separated by a double-tray sizing device (Seedburo Equipment Co., Chicago, IL). Head brown rice yield was expressed as a percentage of head brown rice mass to dried rough rice mass.

2.4. Physical properties

The color attributes of whiteness (L^*) and yellowness (b^*) of rice before and after soaking were measured using a Hunter lab digital colorimeter (Colorflex EZ, Hunterlab, Reston, VA) and determined by CIE color scales. The colorimeter was standardized using a white blank (Iluminat D65 10° Observer, $x = 79.88$, $y = 84.72$, $z = 89.47$) with a 31.8-mm aperture. Approximately 30 g of head brown rice was filled in a clear, flat-bottom dish and placed at the center of the sample port for the measurement. The cup was rotated 180° for the second reading.

The chalkiness was measured by an image analysis system (Winseedle™ Pro 2005a Regent Instruments Inc., Sainte-Foy, Quebec, Canada). Several chalky and translucent kernels were scanned and used as references for the system to classify the chalk and translucent area based on number of pixels. To determine the chalkiness, one hundred random rice kernels were placed in a tray made from a 2-mm thick clear acrylic sheet (Plexiglass) with no kernel touching another, and then imaged with a scanner (Epson Perfection V700 Photo, Model# J221A, Seiko Epson Corp., Japan). The system measured the number of pixels and classify them according to the pre-set criteria. Chalkiness was expressed as percentage of the number of pixels in chalky area over the number of pixels in total kernel projected area.

2.5. Gelatinization properties

Brown rice was ground into flour using a UDY cyclone sample mill (UDY Corp., Ft. Collins, CO) fitted with a 0.50-mm sieve. The gelatinization properties of rice samples were determined using a differential scanning calorimeter (DSC, Diamond, Perkin-Elmer Co., Norwalk, CT). Approximately 4 mg of brown rice flour was measured into an aluminum sample pan and added with 8 μL of deionized water. The sample pans were then sealed and kept at room temperature for 1 h prior to scanning from 25 °C to 120 °C at 10.0 °C/min. Onset (T_o), peak (T_p), and conclusion (T_c) temperature as well as gelatinization enthalpy (ΔH) were determined.

2.6. Pasting properties

The pasting properties of brown rice flour were characterized using a Rapid ViscoAnalyser (Newport Scientific Pty. Ltd, Warriewood, NSW, Australia). Rice slurry was prepared by mixing 3.0 g of rice flour (12% moisture basis) with 25.0 mL of water, and heated from 50 °C to 95 °C at 4 °C/min, held at 95 °C for 5 min, and then cooled to 50 °C at 4 °C/min and held at 50 °C for 2 min. Data were collected using the RVA software – Thermocline for Windows.

2.7. Statistical analysis

Experiments were conducted in triplicate. The differences in mean values of each rice properties among samples were evaluated using one-way ANOVA with Tukey's HSD. The effects of soaking temperatures and T_o difference including their interactions and relative importance of both factors were examined using two-way ANOVA. All statistical analyses were carried out at $\alpha = 0.05$ using JMP software version 12.0.0 (SAS Software Institute, Cary, NC) using