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Optimization of instant jasmine rice process and its physicochemical properties

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ABSTRACT

Instant, or quick-cooking, rice is becoming more popular nowadays. However, it still poses problems with respect to rehydration time and quality. This study investigated the effects of processing factors: moisture content, pressure and drying temperature on physical and physicochemical properties of instant rice and its eating quality using response surface methodology (RSM). Hardness, chewiness and the whiteness index (WI) were used as responses due to their high R^2 (0.927, 0.633 and 0.836, respectively) and lack-of-fit. The hardness and chewiness of rice decreased as moisture content and pressure increased. Higher drying temperatures caused increases in hardness and chewiness. Only pressure and moisture content affected density, rehydration ratio, and increase in the volume of instant rice, which was due to the porosity of the kernels. Rehydration ratio had a negative correlation with density ($r = -0.886$) but a positive correlation with volume increase ($r = 0.637$). Pressure was the main factor influencing the pasting properties of instant rice. All pasting properties of instant rice were far lower than those of milled rice, but instant rice had higher cold paste viscosity, which is typical of pregelatinized flour. This indicated rapid water absorption and shorter cooking time. Instant rice processing also caused development of amylose–lipid complexes observed as the V-type pattern in an X-ray diffractometer.

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1. Introduction

In modern lifestyles, instant food is becoming more popular. However, instant rice is still beset by the problems of long rehydration time and inferior quality compared to cooked milled rice. The texture of cooked rice is related to its amylose content and the fine structure of amylopectin. The intra- and/or intermolecular interactions of starch with other components in rice such as protein, lipid and non-starch polysaccharides results in a harder texture (Ong and Blanshard, 1995). Moreover, processing conditions also affect the texture of cooked rice in a way similar to the parboiling process. The basic processes in preparing instant rice and parboiled rice are similar, consisting of soaking, steaming and drying. These processes have marked impacts on the organoleptic properties of cooked rice. Derycke et al. (2005a) found that the heat-moisture conditions during parboiling, cooling and drying had impact on cooked parboiled rice. They observed that the texture of cooked parboiled rice was usually firmer and less sticky than that of non-parboiled rice. This firmer texture was related to the level of crystalline amylose–lipid complexes formed during parboiling which were stable during the cooking process.

According to Robert (1972), dry grains of instant rice should be separate and should resemble milled rice in shape. Its bulk density should be 0.4–0.42 g/cm^3 with a low percentage of broken kernels. After rehydration, the volume of instant rice should increase to 1.5–3 times that of dry grains, and its color, flavor and texture should be similar to cooked rice (Smith et al., 1985) with no hard core or ungelatinized center (Luh et al., 1980). Previous investigators tried to propose instant rice processes which were mainly concerned with three main factors: (1) the initial moisture content, (2) the degree of gelatinization and (3) the drying or puffing method. The initial moisture content could be manipulated by the temperature of the water used in soaking and/or time. The initial moisture content has been reported to affect the product's homogeneity (Baz et al., 1992), degree of gelatinization, percentage of broken kernels (Ahromrit et al., 2006) and degree of starch leaching (Bello et al., 2006). Degree of gelatinization was related to cooking method, cooking time and/or temperature. Partial gelatinization (around 80%) (Smith et al., 1985) or complete gelatinization either by boiling or steaming have been proposed as necessary in the instant rice preparation process. High pressure cooking process resulted in more homogeneous gelatinization and reduced the percentage of broken kernels (Bhattacharya, 1985; Baz et al., 1992). Drying processes varied from single step drying at low temperature (70 °C) for a long time (2–3 h) to multi-step drying at high temperature for a short time to induce case hardening followed by low temperature drying for a long time to reduce moisture content (Robert, 1972; Ozai-Durrani, 1948). Other drying methods included the use of tray dryers or centrifugal fluidized bed dryers (Baz et al., 1992; Ramesh and Rao, 1996; Carlson et al., 1979), drum dryers (Robert, 1972; Lewis and Lewis, 1991; Ando et al., 1980), a

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freeze–thaw process (Robert, 1972) and high pressure cooking (Leelayuthsoontorn and Thipayarat, 2006; Bhattacharya, 1985; Baz et al., 1992).

In this study, response surface methodology (RSM), an empirical modeling technique used to estimate the relationship between a set of controllable experimental factors (Myers and Montgomery, 2002), was applied to optimize the instant rice preparation process. The process factors with the greatest effect on instant rice product quality were investigated together with their interactions. Moreover, the changes in physical and physicochemical properties during the instant rice preparation process were also studied in order to understand their relationships with the product and its eating quality.

2. Materials and methods

2.1. Raw materials

A sample of the inbred KDML 105 rice variety was obtained as paddy from the Thailand Rice Research Institute. The paddy samples were dehusked using a McGill sample sheller (dehusker), and the rice bran was removed using a McGill No. 2 mill. Samples were milled to a constant degree of milling (DOM = 90). The DOM was measured using a Satake Milling Meter MM-1B. The white rice was packed in plastic bags and kept at 4 °C.

2.2. Experimental design

A five-level, three-variable central composite design (CCD) was applied to estimate the relationship between variables concerning texture and the whiteness index (WI) of instant rice. CCD consisted of eight factorial points, six axial points (two axial points on the axis of each design variable at a distance of 1.68 from the design center) and six center points, leading to 20 sets of experiments. The experiments were run in random order to minimize the effects of unexpected variability in the observed responses due to extraneous factors.

Milled KDML 105 rice was soaked in water for various soaking times to obtain moisture contents of 35–60% wet basis (X_1; −1.68 to +1.68 level). After soaking, the rice grains were cooked under pressures of from 11.6 to 28.4 lb/in^2 (or 8.00×10^4 to 19.58×10^4 Pa) (X_2; −1.68 to +1.68 level) for 5 min. Then, the cooked rice was dried using a tray dryer at temperatures from 166.4 to 233.6 °C (X_3; −1.68 to +1.68 level) to obtain a product with a moisture content of less than 12%. The variables and their process levels are shown in Tables 1 and 2.

Regression analysis was performed based on the experimental data and was fitted to an empirical second order polynomial model as shown in the following equation:

$$Y = \beta_0 + \sum_{i=1}^{3}\beta_i X_i + \sum_{i=1}^{3}\beta_{ii} X_i^2 + \sum_{i=1}^{2}\sum_{j=i+1}^{3}\beta_{ij} X_i X_j + e \quad (1)$$

where Y was the response variable, B_0, B_i, B_{ii}, B_{ij} were the regression coefficients of variables for intercept, linear, quadratic and interaction terms, respectively, and x_i and x_j were independent variables.

Table 1
Coded levels for independent variables used in developing experimental data.

Factor	Code	Level				
		−α (−1.68)	−1	0	+1	+α (1.68)
Moisture Content (% wb)	X_1	34.90	40	47.5	55	60.10
Pressure (lb/in^2)	X_2	11.60	15	20	25	28.40
Drying Temperature (°C)	X_3	166.36	180	200	220	233.64

For optimization and validation; cooked rice prepared from electric cooker was used as control sample. The model with no significant lack-of-fit and high R^2 was selected. The optimum conditions were those which gave no significant differences from control sample. Validation was obtained by comparison the attributes that gave no significant lack-of-fit and high R^2 between real value and prediction value using *t*-test at 95% level of confidence.

2.3. Density, rehydration ration and volume increase

2.3.1. Density

Dry instant rice was put in 100-ml cylinder and tapped 25–30 times to allow uniform compacking of grain, then recorded the volume and weighted the instant rice in the cylinder. Density was calculated by:

$$\text{Density} = \frac{\text{weight of instant rice (g)}}{\text{volume of instant rice (ml)}}.$$

2.3.2. Rehydration ratio

Rehydration ratio was determined using 10 g of dry instant rice added with 100 ml water heated by microwave for 6 min, drain the excess water for 5 min, and then weighed. The rehydration ratio was calculated as weight of rice before and after cooking:

$$\text{Rehydration ratio} = \frac{\text{weight of instant rice after cooking (g)}}{\text{weight of instant rice before cooking (g)}}.$$

2.3.3. Volume increase

Volume increase was determined by measuring the volume of 20 g of instant rice before and after cooking by microwave 6 min using graduated cylinders tapped 25–30 times to allow uniform compacking of grain. The volume increase calculated as the volume of rice before and after cooking as:

$$\text{Volume increase} = \frac{\text{volume of rice after cooking (ml)}}{\text{volume of rice before cooking (ml)}}.$$

2.4. Scanning electron micrographs (SEM)

SEMs of instant rice samples were taken with a Hitachi Table-Top/Tischmikroskop model TM-1000 at magnitude x 80. The samples were prepared by breaking a rice kernel at the center and sticking it on the stub without gold film coating.

2.5. Texture profile analysis (TPA)

Thirty grams of instant Jasmine rice was rehydrated with 110 ml water and microwaved for 6 min. TPA was performed using a texture analyzer (TA-XT.plus, Stable Micro System, UK). Following Park et al. (2001), 10 g of rehydrated rice was molded into a block using a cylindrical container. It was compressed to 60% with a rod-type probe (2.5 diameters) at a speed of 1.7 mm/s. Hardness, adhesiveness, springiness, cohesiveness, gumminess and chewiness were determined.

2.6. Whiteness index (WI)

The whiteness of rehydrated rice was measured using a colorimeter (Chromameter model CR-300, Japan). Measurement was based on the Hunter system with color values of *L*, *a* and *b*. The measurements were performed in two replications and were repeated three times per replicate. The whiteness index (WI) was calculated as follows:

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