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Effect of drying involving fluidisation in superheated steam on physicochemical and antioxidant properties of Thai native rice cultivars

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ABSTRACT

This paper is aiming at investigating the effects of drying process on physicochemical and antioxidant properties of Thai native rice cultivars Sung Yod Phattalung and Nauykaur. A combination of fluidisation and superheated steam is the selected protocol for the first stage of drying. Two-stage drying process, i.e. fluidisation drying under superheated steam as a medium followed by shade drying at ambient temperature is employed to dry wet Thai native paddy at 170 °C for different length of time (2.5–4 min), then followed by shade drying at ambient temperature until the final moisture content of the paddy comes down to 13–14% (w.b.). The results of physicochemical and antioxidant properties of native paddy after drying showed that the longer drying time in superheated steam resulted in changes of pasting properties such as peak viscosity, breakdown, final viscosity and set back of the native rice. The values of the pasting properties decreased while pasting temperature increased. The antioxidant activity of Sung Yod Phattalung was reduced, but that of Nauykaur increased when drying time in superheated steam increased.

1. Introduction

Rice is the main source of staple food in Thailand. Thailand produced more than 31.6 million tonnes of rice in 2011–2012 (Thai Rice Exporters Association, 2012). In Thailand, the rice research focuses on breeding of new varieties in order to maximize the crop yield, resistant to disease and high growth rate. Therefore, Thai native rice cultivars have been neglected and get little attention, since they have low product yield and slow growth rate. However, some Thai native rice cultivars have high nutrient content. For example, Sung Yod Phattalung rice, which is native rice from the southern part of Thailand, contains higher amounts of vitamin B2, niacin, proteins and phosphorus than Thai Jasmine rice. Nauykaur rice has high vitamin E which is well known for antioxidant properties (Phattalung Rice Research Centre, 2007).

Nowadays, people are increasingly concerned about their health and quality of life. Processed food receives now less attention from consumers. Fresh food, minimally processed food, or food that contains special ingredients needed for specific purposes are becoming more popular. The popularity of functional food is increasing and get more attention from consumers.

More than two decades of research on paddy drying in Thailand have passed and outcomes of this research have produced significant benefits to Thai rice industry. One of the achievements from the research is applying high temperature drying process using fluidization technique combined with ambient air drying (two-stage drying) to reduce paddy's moisture content down to a safe storage level of 14% (w.b). High temperature drying has been introduced to the rice industry in Thailand in order to solve the problem of post-harvest handling of wet paddy (Soponronnarit, 1996).

The advantages of this technique that it is significantly increasing head rice yield and reducing drying time. Drying paddy at a high temperature for a short period of time promotes partial gelatinisation and/or melting of starch granules at the surface and inside the rice kernel. In the second stage of paddy drying, rice kernel is tempered at exit grain temperature for 30–45 min to create uniform gradient of moisture content. Then paddy is dried under ambient air flow until moisture content is reduced to a safe level for storage. During ambient air drying, the temperature of the grain is decreased, thus starchy fluid inside the grain becomes hard and tough. In this way, the grain kernel is strong and can withstand breakage during milling. Consequently, head rice yield is increased when employing this two-stage process combining fluidised bed drying with tempering and ambient air drying. The physical changes of rice granule which occurred as the result of partial gelatinization and/or melting of starch granules during two-stage high temperature fluidised bed drying lead to specific characteristics of cooked rice that is similar to aged rice. Therefore, two-stage drying using high temperature fluidization technique combined with ambient air drying can also be used for accelerating rice aging process.

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Two-stage high temperature fluidisation drying of rice can promote the formation of amylose–lipid complex inside rice kernel and this complex decreases glycemic index (GI) and resistance to digestion. This is of benefit to people who need to control their blood sugar balance (Jaisut et al., 2008).

Superheated steam has been used in drying process in production of several dried products such as longan (Somjai et al., 2009), chicken meat (Nathakaranakule et al., 2007), shrimp (Namsanguan et al., 2004), rice (Rordprapat et al., 2005; Taechapairoj et al., 2003). The advantages of employing superheated steam as the drying medium are high drying rate, low energy consumption and non-polluting as well as preservation of color, nutritional value and shrinkage of products (Li et al., 1999; Moreira, 2001).

It was found that using fluidization with superheated steam at 150 °C can increase head rice yield more than using hot air at 150 °C as heating medium (Rordprapat et al., 2005). In addition, a study made by Taechapairoj et al. (2003) noted that % head rice yield and whiteness of rice dried under superheated steam at 170 °C were higher than superheated steam at 150 °C.

Therefore, this research aims to study the effect of fluidization drying technique combined with superheated steam on physico-chemical properties and antioxidant properties of Thai native rice, namely cultivars Sung Yod Phattalung and Nauykaur. The information obtained from the research will be used for the development of functional rice products.

2. Materials and methods

2.1. Materials

Two varieties of Thai rice (*Oryza sativa* L.), namely Sung Yod Phattalung (S) and Nauykaur (N), were obtained from Rice Research Center at Phattalung province of Thailand. The initial moisture content of obtained paddy was 24–26% (w.b.). Paddy samples were stored in the cold room at 4 °C until the drying experiments could be carried out.

2.2. Drying process

Rice samples were dried using a superheated steam fluidized bed dryer (in-house custom made laboratory apparatus) at drying medium temperature of 170 °C for 2.5, 3 and 4 min. The samples were then subjected to shade drying until moisture content came down to 12–14% (w.b.). Control sample of both Sung Yod Phattalung and Nauykaur were shade dried only. Moisture content and proximate composition of paddy was determined according to standard method of AOAC (2000). Each measurement was done in triplicates and the average percentage of moisture content on a wet basis (g/100 g sample) and each proximate composition content on a dry weight basis (g/100 g solid) were reported.

2.3. Apparent amylose content

Amylose content of rice samples was determined by spectrophotometric method as described by Juliano (1972). Each measurement was done in triplicates and the average percentage of apparent amylose content on a dry weight basis (g/100 g solid) was reported.

2.4. Pasting properties

Milled rice was ground to flour using a centrifugal miller. It was then passed through a 149 μ (100-mesh) sieve. Pasting properties of the flour samples were determined using a Rapid Visco Analyzer (RVA, model Super 3, Newport Scientific, Australia). The samples (3.0 g) were made equivalent to 12% moisture content and mixed with distilled water in a canister to make a total weight of the slurry of 28 g. A programmed heating and cooling process was followed: holding at 50 °C for 1 min, heating to 95 °C for 3.7 min, holding at 95 °C for 2.5 min, cooling to 50 °C for 3.7 min and then holding at 50 °C for 1.5 min. The rotational speed was 960 rpm in the first 10 s and then maintained at 160 rpm until the end. The RVA instrument provided the following parameters;

- Peak viscosity (PV) – the highest viscosity during heating;
- Breakdown (BD) – peak viscosity minus trough;
- Final viscosity (FV) – the viscosity at the completion of the cycle;
- Setback (SB) – final viscosity minus peak viscosity;
- Pasting temperature (PT) – temperature where viscosity first increases.
- Determination of swelling properties following Scoch (1967).

Each measurement was done in triplicates and the average value was reported.

2.5. Crystallinity of rice flour

Crystallinity of rice flour was determined by using X-ray diffraction (Bruker axs, model D8 Advance, Germany), with the X-ray generator producing monochromatic copper K radiation (wavelength = 1.542 A) operating at 30 kV and 40 mA. Milled rice flour was tightly packed into sample holder. The diffraction data were collected over an angular range from 4° to 30° 2θ. The X-ray diffraction patterns were visually compared with the peak characteristics of theoretical diffraction given by Zobel (1964). Percentage of crystallinity was calculated as the ratio of area of the crystalline sharp peak over the area.

2.6. EC_{50} and total phenolic content

The antioxidant properties of the Thai native rice were determined by using 2, 2-diphenyl-1-picrylhydrazyl (DPPH) method and the antioxidant power reported in term of EC_{50}. This method followed Tananuwong and Tawaruth (2010) with slight modification. Total phenolic content was determined by using Folin–Ciocalteu method and reported into gallic acid equivalent. Each measurement was done in triplicates and the average value was reported.

3. Results and discussion

Sung Yod Phattalung rice is native rice from Phattalung province in southern Thailand. The rice kernel has purple pericarp and long grain. Nauykaur rice is short grain and mainly found in central part of Thailand. Both Sung Yod Phattalung and Nauykaur have high nutritional value especially protein and vitamin content (Phattalung Rice Research Centre, 2007). The proximate composition of Thai native rice after drying is shown in Table 1.

Table 1
Proximate composition of Thai native rice cultivar after drying.

Proximate composition	Sung Yod Phattalung	Nauykaur
Moisture content (% wet basis)	11.40 ± 0.22	12.82 ± 0.19
Protein (% dry basis)	10.45 ± 0.39	11.08 ± 0.25
Fat (% dry basis)	4.24 ± 0.2	2.84 ± 0.33
Ash (% dry basis)	1.57 ± 0.07	1.77 ± 0.11
Carbohydrate (% dry basis)	72.34 ± 0.46	71.49 ± 0.30
Apparent amylose content (% dry basis)	13.48 ± 0.29	20.43 ± 0.54