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Effects of inlet air temperature and spray rate of coating solution on quality attributes of turmeric extract coated rice using top-spray fluidized bed coating technique

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A B S T R A C T

The addition of natural antioxidants onto white rice kernel can improve its functionality. Curcuminoids that present in turmeric rhizomes possess high antioxidant activity and heat stability. The objective of this study was to investigate the effects of inlet air temperatures and spray rates of turmeric extract solution on quality attributes of the turmeric extract coated rice (TCR) using the top-spray fluidized bed coating technique. The experimental results have shown that inlet air temperature and spray rate of coating solution strongly affected the final moisture content and percentage of fissured kernel of TCR. Almost all of TCR kernels in the bed cracked when their final moisture content was lower than 11.8% wet basis. However, the head coated rice yield of fissured TCR slightly decreased from that of white rice. The color of TCR was uniform over the entire surface. Texture of cooked TCR insignificantly changed from that of uncoated sample. Increasing spray rate provided higher both total phenolic content (TPC) and total antioxidant capacity (TAC) whilst increasing inlet temperature yielded lower TPC but it did not affect TAC. Retentions of TPC and TAC of TCR after cooking remained higher than 90%.

1. Introduction

Foods that have natural ingredients or natural additives are preferred by consumer. Natural antioxidants are one of the food additives used to extend the shelf life and improve nutritional value and functionality of foods. Phenolic compounds which are one of natural antioxidants are widely used as additive of many foods because they have many benefits to health (Larson, 1988; Gerber et al., 2002; Kim et al., 2003; Kris-Etherton et al., 2002; Jang et al., 2007; Wojdylo et al., 2007; Tawaha et al., 2007).

Curcuminoids which mainly consist of curcumin, demethoxycurcumin and bisdemethoxycurcumin are a major active component of turmeric rhizomes (Jayaprakasha et al., 2005). They have been found to be a rich source of phenolic compounds that possess high antioxidant activity. Many researches have reported about the biological, physiological and chemical properties of the curcuminoids, for example anti-inflammatory, antimicrobial, antiparasitic, antitumor, antiviral and antimutagenic (Polasa et al., 1991; Selvam et al., 1995; Ruby et al., 1995; Ahsan et al., 1999; Masuda et al., 1999; Ramsewak et al., 2000; Jayaprakasha et al., 2006; Ak and Gülçin, 2008; Itokawa et al., 2008). Curcuminoids are also moderately stable to heat (Khatun et al., 2006; Temitope et al., 2010; Paramera et al., 2011).

Rice is one of the leading cereals worldwide and it is a staple food of over half of the world's population (Juliano, 1990). White rice or milled rice is more favorite to consumer than brown rice although nutritional value and phytochemicals content of brown rice are higher than white rice. This is because the bran layers that are a rich source of minerals, vitamins and phytochemicals including antioxidants are removed from rice grain during milling process (Choi et al., 2007; Shen et al., 2009). Coating the white rice with turmeric extract is a possible way to improve its antioxidant property.

There are many ways to coat the solid particles with some substances. The rotating pan, rotating drum, fluid bed and other mixers are given as for example. Of these, the spray coating in the rotating pan and fluid bed are most widely used for the coated particles (Maronga, 1998). In the rotating pan coating process, particles are moved by rotating a pan and the coating solution is then

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sprayed onto the surface of particles. The hot air is used to dry the deposited solution to form a coating layer on the particle surface. This method has widely been used for a long time, but the rotating pan has yet a low reproducibility and it is not suitable for coating particles that require high coating uniformity (Maronga, 1998). On the other hand, fluidized bed coating technique has been increasingly applied in the food industries (Dziezak, 1988; Dewettinck and Huyghebaert, 1999; Werner et al., 2007). There are three different configurations for this coater but the top-spray has a greater possibility of success in the food industries when compared to bottom-spray and tangential-spray. This is due to its high versatility, relatively high batch size and relative simplicity (Dewettinck and Huyghebaert, 1999). With top-spray fluidized bed coating the coating solution is sprayed onto the surface of fluidizing particles by a nozzle that may be placed above the bed or submerged inside the bed. The coating solution that is adhesive on the particle surface is dried due to the heat supplied by the fluidizing gas. The advantage of this coating technique is that the coating and drying takes place simultaneously in only one unit operation. Moreover, it can be used to coat the particle that has size in the range from 0.1 to several millimeters (Guignon et al., 2002).

In this work, the top-spray fluidized bed coating technique and turmeric extract were therefore chosen to coat white rice and the effects of operating parameters including inlet air temperature and spray rate of coating solution on quality attributes of turmeric extract coated rice (TCR) were investigated. Quality attributes of the TCR were evaluated in terms of moisture content (MC), percentage of fissured kernel, head coated rice yield, color, textural properties, total antioxidant capacity (TAC) and total phenolics content (TPC).

2. Materials and methods

2.1. Materials

Jasmine white rice (Khao Dawk Mali-105) that used in this study was purchased from Chia Meng Company, Bangkok, Thailand. It had an equivalent spherical diameter of 3.43 mm and true density of 1419 kg/m^3. The turmeric extract powder was purchased from Specialty Natural Products Company, Chonburi province, Thailand. The white rice and turmeric extract powder were stored in a dark room at temperature of 4–6 °C prior to an experiment.

2.2. Top-spray fluidized bed coating configuration

Fig. 1 shows a schematic diagram of a small scale batch top-spray fluidized bed coating apparatus. This system consists of two main parts, fluidized bed unit and spraying unit. In the fluidized bed unit, it consists of a stainless steel coating chamber with an inner diameter of 0.27 m and height of 1 m. A high-pressure blower (Venz, model HB 2.2, Thailand) was used to supply the fluidizing air. The velocity of inlet air was adjusted by butterfly valve and measured by the hot wire anemometer (Testo, model 445, Lenzkirch, Germany). The inlet air temperature was heated by electric heater and its temperature was controlled by proportional-integral–differential (PID) controller (Linking, model LT400, Taiwan). The heated air enters the bed through the air distributor plate that was made from a stainless steel perforated plate. The perforated plate had a hole diameter of 1.5 mm. The exhaust air flowed through the cyclone separator in order to remove the dust and then the clean air about 80% of total exhaust air was reused again. In the part of spraying unit, the diaphragm dosing pump (Grundfos, model Alldos DMS 12–3, France) was used to supply the coating solution to the internal mixing two-fluid nozzle (Spraying system, USA). The nozzle was a downward facing and located in the bed at 0.21 m height from the distributor plate. The atomization air was supplied by air compressor and its pressure was controlled by pressure regulator.

2.3. Experimental procedure

2.3.1. Turmeric extract solution preparation

The turmeric extract powder was slowly dissolved in 70% (v/v) of ethanol solution to obtain turmeric extract solution at the concentration of 4% (w/v). The turmeric extract solution was then filtered through four layers of white cloth. Finally, the concentration of ethanol in the filtered solution was diluted to 40% (v/v) by adding some distilled water.

2.3.2. Coating procedure

Five kilograms of white rice was fed into coating chamber via inlet hopper and at this amount it corresponded to the static bed height of 10 cm. As soon as the fluidizing air reached a desired inlet air temperature, the coating solution was sprayed from the nozzle. The experimental conditions were carried out at spray rates of coating solution of 34, 40 and 46 mL/min, atomization air pressure of 1.5 bar (gauge pressure), spraying time of 12 min, inlet air velocity of 3 m/s, which is 2.7 times of minimum fluidization velocity, inlet air temperatures of 50, 55 and 60 °C and the percentage of recycle air of 80. After stopped spraying, the coated rice was dried for 5 s and then the coated rice was kept in a sealed plastic bag at temperature of 4–6 °C before quality analysis.

2.4. Moisture content determination

Moisture content (MC) of TCR was determined by drying 30 g coated rice sample at 103 °C in a hot air oven for 72 h (Memmert, model ULE500, Schwabach, Germany). The measurement was carried out in triplicate of each experiment and an average value was reported.

2.5. Fissure determination

The determination of fissure was performed by randomly choosing 100 TCR kernels and each kernel was inspected using visual inspection with modified method of Iguaz et al. (2006). The TCR kernel was inspected by visual inspection through the magnifying glass under the light from fluorescent bulb. The magnifying glass was placed over the sample about 15 cm. The inspections were repeated five times for each experiment and the average value was presented.

2.6. Head coated rice yield determination

The broken TCR in 200 g sample was separated using an indent cylinder separator (Satake, model TRG-05A, Hirochima, Japan) and the head coated rice was determined (Jaisut et al., 2008; Jaiboon et al., 2009). The broken TCR is defined as TCR that has the kernel length less than 75% of its original length. After separation, a separated sample remained only head coated rice and the head coated rice yield of TCR was calculated by dividing the head coated rice mass of TCR by total sample mass. The measurement was performed in triplicate and the result was presented by average value.

2.7. Color measurement

The color of TCR was measured by spectrophotometer (model ColorFlex, HunterLab Reston, VA, USA) with a D65 illuminant and observer angle of 10°. The CIE L*a*b* color scale was used as color descriptor. Before measuring TCR color, the colorimeter was