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Quality attributes and anthocyanin content of rice coated by purple-corn cob extract as affected by coating conditions

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ABSTRACT

We investigated the optimal conditions for coating rice with the water extract of purple-corn cob (PCC) using a top-spray fluidized bed coating method with variations of inlet air temperature of 50, 60 and 70 °C and spraying time of 5, 10 and 15 min. The results showed that increasing the inlet air temperature significantly reduced the final MC. Fissured coated rice increased with increasing temperature and spraying time. The percentage of head rice yield was not affected by inlet temperature, while it tended to decrease with longer spraying time except at 15 min. In addition, longer spraying time resulted in higher values of chroma implying a larger amount of coating solution. We also found that increasing the temperature decreased the total phenolic, total flavonoids and total anthocyanins contents as well as their antioxidant activities as determined by DPPH and FRAP assays. In contrast, those values were increased when the spraying time increased. The same trend was found for anthocyanin composition. Based on the optimization criteria with the highest desirability of 0.702, we recommend an inlet air temperature of 50 °C and spraying time of about 15 min to obtain the minimum fissure and maximum coating material.

1. Introduction

Rice is a staple food consumed worldwide, particularly in Asia. Even though brown rice has a higher nutritional value and phytochemicals content, including antioxidants, white rice or milled rice has been preferred by consumers due to its flavor and texture. In order to maintain such values, adding a natural extract containing antioxidants to white rice is taken into considered as an improvement of its health benefits.

Anthocyanins are flavonoid pigments providing colors that vary from orange, red, violet, blue and dark purple in vegetables and fruits such as grapes, blueberry, blackberry, raspberry, purple carrot etc. (Wang et al., 1997; He and Giusti, 2010). They have been widely used as natural colorants due to their low toxicity. Anthocyanins have been reported to have high antioxidant properties which are correlated with the prevention of chronic diseases in humans (Yang and Zhai, 2010; Flanigan and Niemeyer, 2014) such as cancers, cardiovascular disease and others. For example, consumption of a diet containing anthocyanins is associated with neuroprotective effects, such as a decreased risk of Parkinson's disease (Flanigan and Niemeyer, 2014). However, anthocyanins are highly unstable to processing, especially thermal processing (Vegara et al., 2013). Furthermore, due to the high cost of such vegetables and fruits, many attempts have been made to find other potential natural sources, as summarized in (Fu et al., 2011; Deng et al., 2013; Morales-Soto et al., 2014).

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Purple corn originated from Peru and is one of rich sources of anthocyanins. It contains not only higher anthocyanins than those of the aforementioned vegetables and fruits, but its price-per-unit is also much lower (Cevallos-Casals and Cisneros-Zevallos, 2004). Purple corn has now been gaining popularity for consumption in many regions including Thailand. It is consumed on the cob as fresh food after being cooked by boiling water or steaming (Harakotr et al., 2014). The corn cob is normally thrown away as waste, even though it contains as many bioactive compounds, especially anthocyanins as in the corn seed. Therefore, the purple-corn cob could be a cheap potential natural source of anthocyanins and other bioactive components.

Recently, rice coated with natural extracts containing antioxidants or other bioactive compounds has been considered as value-added product gaining more popularity in the market. Coating the solid particles can be made by means of a rotating drum, rotating pan, fluid bed or other mixers (Teunou and Poncelet, 2002). Among them, the rotating pan and fluid bed are associated with coating spray and are most appropriate in this application (Maronga, 1998). However, the former is still not a suitable technique in the food industries when compared with the fluidized bed coating process which provides higher reproducibility and coating uniformity (Maronga, 1998; Palamanit et al., 2013). In this process, particles at the bottom are fluidized by a continuous air stream blown through an air distributor. Coating solution is pumped and subsequently atomized through a nozzle and sprayed onto the surface of particles, resulting in wet particles. The deposited solution is subsequently dried by the hot air, leading to formation of layered growth on the particle surface. Among bottom-spray, tangential-spray and top-spray configurations, the latter in which a nozzle may be positioned above or submerged inside the bed has been successfully employed in the food industry due to its high flexibility and simplicity of high batch size (Duangkhamchan et al., 2015).

Due to a unique operation providing simultaneous processes (coating and drying) taking place in only one apparatus, Palamanit et al. (2013) applied the fluidized bed coating process to improve functional properties of white rice. They improved the antioxidant property of white rice by coating turmeric extract solution by means of a fluidized bed coating technique with top-spray configuration. That work revealed high potential to increase total phenolic content and total antioxidant capacity of white rice. In addition, the experimental results showed the influence of operating parameters including spraying rate and inlet air temperature on physicchemical properties of the coated rice. In order to reduce attrition promoted in the conventional rotating-pan equipment, Solís-Morales et al. (2009) applied a top-spray fluidised bed reactor to coat puffed wheat with sweet chocolate. It can be proven from the two aforementioned publications that the top-spray fluidized bed technique can be potentially applied in the food industry. However, the occurrence of side effects including the premature spray-drying of the droplets containing the dissolved coating material and agglomeration (i.e. sticking or clumping together of wetted particles) could result in poor product quality and product losses (Dewettinck and Huyghebaert, 1999; Werner et al., 2007). To solve these problems, all phenomena in the coating process including air suspension, particle dynamics, coating solution droplet trajectories and their interactions have to be clearly understood so that appropriate selection of process input variables can be achieved (Teunou and Poncelet, 2002).

As a result of various operating variables, i.e. process conditions, material properties, affecting the coating process dynamics and quality of the resulting product, many attempts have been made to optimize the coating system, improving the reactor design and increasing material efficiency, as reviewed by Teunou and Poncelet (2002). For instance, Atarés et al. (2012) investigated the effects of core materials on the layer growth mechanism as well as coating quality. In addition to core material properties, the effects of process variables on quality attributes were studied by Palamanit et al. (2013). Process optimization has not only been carried out experimentally, but has also been studied by means of mathematical models (Perfetti et al., 2012). Since the quality of coated products is greatly affected by the operating variables, multivariate analysis such as response surface method widely applied to food process optimization could be a potential means to investigate the relationships between the process and end-product quality. Therefore, in this work, the effects of inlet air temperature and spraying time on physical attributes of rice coated with purple-corn cob (PCC) in terms of percentage of fissured kernel, head rice yield and chroma were investigated by means of response surface methodology. Subsequently, it was applied to optimize the top-spray fluidized bed coating condition for white rice coated with purple-corn cob extract. Also anthocyanin and phenolic contents along with their antioxidant activities were included. We expect to obtain an appropriate coating condition for preserving both physical and antioxidant properties of rice coated with PCC.

2. Materials and methods

2.1. Materials

2.1.1. Rice sample

Milled rice variety Khao Dawk Mali 105 (KDML 105) harvested from Maha Sarakham province, Northeastern Thailand, was used in this work. Prior to testing, its moisture content, %head rice yield and %fissure were analyzed, and the rice sample was kept in a dark room at temperature of $4 \pm 1\,^{\circ}$C.

2.1.2. Purple-corn cob extract solution preparation

Purple-corn cobs (*Zea mays* L. var. ceratina) provided by Assistant Professor Sakulkarn Simma, Department of Agriculture Technology, Faculty of Technology, Mahasarakham Univerisity, Thailand, were sliced into small pieces. One hundred and fifty grams of sliced cob were boiled (85–95 °C) in 100-ml distilled water for 10 min. The extract was subsequently filtered through multi layers of white cloth. The extract was measured for total soluble solid (TSS), $2.0 \pm 0.1\,^{\circ}$Brix. Finally, the purple-corn cob extract was mixed with maltodextrin (dextrose equivalent, DE = 10) of approximately 0.7 g/g of purple corn extract in order to obtain the 15 °Brix solution used as a coating material, and was then stored prior to use in a dark room at $4 \pm 1\,^{\circ}$C.

2.2. Experimental setup

A laboratory scale top-spray fluidized bed coater consisted of a conical stainless steel vessel with an inclination of 8.1° (a top diameter of 0.30 m, a base diameter of 0.14 m and a height of 0.56 m). A stainless perforated plate with a hole size of 1 mm was used as an air distributor at the bottom of the vessel. Fig. 1 shows a schematic diagram of the apparatus. The fluidizing air was supplied using an 1-hp blower associated