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Research Article
Effects of Spray Drying at Different Inlet Air Temperatures on Antioxidative Activity and Some Properties of Homnil Rice Bran Extract Powder

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Abstract

Background and Objective: Homnil rice bran (HRB) contains unstable bioactive compounds. Spray drying temperatures might affect on the antioxidative activity and other properties of HRB extract (HRBE) powder. Therefore, the objective of this work was to study the influence of spray drying at different inlet air temperatures on the antioxidant activity and some properties of HRBE powder. **Materials and Methods:** HRBE obtained from 2% citric acid extraction was added with 10DE maltodextrin and spray dried at various inlet air temperatures (100, 120 and 140°C). The effects of spray drying at different inlet air temperatures on their total phenolic content (TPC), total anthocyanin content (TAC) and DPPH scavenging activity (DPPH) were determined by spectrophotometric methods. The morphological properties were evaluated by scanning electron microscope. **Results:** The results showed that the TPC, TAC and DPPH scavenging activity of HRBE powder that was spray dried with 10 DE maltodextrin at 100°C were equivalent to 305.02 mg gallic acid (GAE)/100 g, 215.12 mg cyanidin per 100 g and 86.14%, respectively. These values were higher than those of the other inlet air temperatures ($p \leq 0.05$). The L*, a* and b* values were 28.23, 38.21 and 3.10. The range of water solubility index (WSI), water absorption index (WAI) and swelling capacity (SWC) of samples in this study was 50.21-59.25, 0.92-1.19 and 2.53-2.90%. The surface of the HRBE powder was smooth at 100°C and the sizes of the powder were in the range of 3-50 µm. The HRBE powder that spray drying with 10DE maltodextrin at the inlet air temperature of 100°C showed a low degradation of total anthocyanins and phenolics. The loss of total antioxidants and color difference were also at a low level. **Conclusion:** The HRBE powder could be prepared by spray drying with 10DE maltodextrin at the inlet air temperature of 100°C and it has a high potential to be used as bioactive food ingredients.

Key words: Homnil rice bran, antioxidative activity, spray drying, total phenolic content, total anthocyanin content, scavenging activity

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Pigmented rice (*Oryza sativa* L.) has been consumed for a long time in Asia, especially China, Japan, Korea and many countries in Southeast Asia. Several varieties of pigmented rice, particularly red and black rice have been cultivated in Thailand. Mice models and human studies showed that pigmented rice has the capability of preventing atherosclerosis[1]. These results may in part be attributed to the presence of natural antioxidants[2]. Pigmented rice were reported to have greater antioxidant capacity than white rice[2,3]. Homnil rice is an economically important rice species. These possesses antioxidants and anti-inflammatory activities[4,5]. Most of the bioactive compounds in Homnil rice bran (HRB) are anthocyanins and other phenolic compounds. However, they are unstable to various factors such as pH, temperature, light and others[6,7]. The spray drier is an economical method for the safe guarding of natural colorants by capturing the ingredients in a coating material[8]. The quality of spray dried food depends on the spray dryer operating conditions. Maltodextrin are water soluble materials and protects encapsulated ingredients from oxidation[9]. They have low viscosity at high solids ratio and are available in different molecular weights which provides different wall densities around the sensitive materials[10]. The degree of polymerization of maltodextrin also influenced the hygroscopicity of the powder[11]. A high degree of polymerization had more hygroscopic and faster water adsorption than a lower degree of polymerization[10-12] prepared anthocyanin powder by spray dried acai juice with 10DE maltodextrin. Higher DE maltodextrins causes an increase in powder moisture content, because of shorter chains and more hydrophilic groups of lower molecular weight maltodextrins[8]. Similar results were reported by Goula and Adamopoulos[13], who studied the effect of 6, 12 and 21 DE maltodextrins on moisture content of orange juice powder. Goula and Adamopoulos[13], further concluded that increased maltodextrin dextrose equivalent has a positive effect on moisture contents. It is due to the fact that high DE maltodextrins develops a stickiness and reaches a state of non-adhesion which is slower than low-DE maltodextrins. The stickier a material is the lower the drying rate will be. Tonon *et al.*[14] also produced bayberry juice which were spray dried with 10 DE maltodextrin. The inlet air temperatures has an important effect on the powder properties such as moisture content, bulk density, particle size, hygroscopicity, antioxidant activity and morphology[15]. Furthermore, the inlet temperatures also influenced the morphology in acai juice powder as reported by Tonon *et al.*[11]. In addition, the inlet temperatures affected the stability of anthocyanin in the acai juice powder. Tonon *et al.*[11] and Quek *et al.*[16] reported that increasing the inlet air temperatures can cause a decrease in solubility and antioxidant activity of orange and watermelon juice powder. They also found that a hard surface layer might be formed over the powder particles at a very high inlet air temperature. This could prevent water molecules from diffusing through the particles. Decreased the wetability of the particle reduced the dissolution of the powder. Spray dried anthocyanins were prepared from blackmulberry juice, acai and bayberry[11,15]. However, spray dried Homnil rice bran extracts has not been previously reported. Therefore, the objectives of this study were to investigate the effects of spray drying at different inlet air temperatures on antioxidative activity and some properties of HRBE powder.

MATERIALS AND METHODS

Materials: The Homnil rice bran samples (*Oryza sativa* L.) were obtained from a local rice milling industry in the Surin province of Thailand. The obtained rice bran was passed through a 60 mesh screen sieve. The Homnil rice bran samples were kept at -18°C for extraction. All chemical reagents were analytical grade.

HRBE preparation: Five gram of Homnil rice bran particle sizes 60 mesh were extracted with 20 mL of 2% citric acid solution and shaking at 150 rpm at 40°C for 3 h. The samples were filtered through a Whatman No.1 filter paper and stored at -18°C until use.

Preparation of Homnil rice bran extract powder by spray drying at different inlet air temperatures: Maltodextrin (MD) was solubilized in deionized water at room temperature (30±1°C). After that, MD was thoroughly mixed with HRBE before spray drying. The spray drying were conducted in a mini spray dryer (B-290, Rikakikai, Tokyo, Japan) under the following operational conditions: The HRBE was added with 10DE MD and spray dried at various inlet air temperatures (100, 120 and 140°C), solid content of 11±0.5 g/100 g, rotary atomizer at 14×10 kPa and blower rate at 0.60±0.2 m^3 min^{-1}.

Analysis of Homnil rice bran extracts powder

Determination of total phenolic content (TPC): The total phenolic content was determined by using the Folin-Ciocalteu reagent according to the method described by Sompong *et al.*[4]. The reaction mixture contained 100 μL of the diluted HRBE, 500 μL of freshly prepared diluted Folin Ciocalteu reagent and 400 μL of 7.5% sodium carbonate. The reaction mixtures were kept in the dark for 2 h at room temperature. The absorbance was measured at 750 nm with an UV-V is spectrophotometer (Shimadzu Corp., Bara Scientific Co., Ltd.). Gallic acid was used as a standard and the results were expressed as mg gallic acid equivalent (GAE)/100g rice bran extract.

Determination of total anthocyanin content (TAC): The total anthocyanin contents in the Homnil rice bran were measured by a pH-differential method[6]. Anthocyanin of the Homnil rice bran extract in 0.025 M potassium chloride buffer (pH 1.0) and 0.4 M sodium acetate buffer (pH 4.5) were measured at 510 and 700 nm. The content of total anthocyanin was calculated by using the following Eq[6]:

$$\text{Anthocyanin contents} = \frac{A \times MW \times DF \times 1000}{\varepsilon}$$

where, MW represents molecular weight of cyanidin-3-glucoside (449.2). DF is the dilution factor (20), ε is molar absorptivity of cyanidin-3-glucoside (26,900 L mol^{-1} cm^{-1}) and A was calculated from the following Eq[6]:

$$A = (A_{510}\text{-}A_{700})_{pH\ 1.0}\text{-}(A_{510}\text{-}A_{700})_{pH\ 4.5}$$

Note that A_{700} was measured and subtracted in order to eliminate the effects of haze or sediments in the sample.

DPPH-scavenging activity (DPPH): Antioxidant capacity was determined by the DPPH (1,1-Diphenyl-2-picrylhydrazyl) assay according to the method of Sharifi and Hassani [17] with some modifications. Each sample was diluted 10-fold in methanol and then a 2 mL subsample was mixed with 2 mL of freshly prepared methanolic solution containing 0.1 mM of DPPH solution. The mixture was shaken vigorously and left to stand for 30 min in the dark. Vitamin C was used as a positive control. The absorbance was then measured at 517 nm. The DPPH scavenging activity was calculated as follows:

$$\text{DPPH scavenging activity (\%)} = \frac{\text{Absorbance of blank} - \text{Absorbance of sample}}{\text{Absorbance of blank}} \times 100$$

Hunter color values: The color attributes (Hunter L*, a* and b* values) were measured with a CM-3500d spectrophotometer (Minolta, Tokyo, Japan) according to the method reported by Ahmed *et al.*[18], with some modifications. Chroma (C*) and hue angle (h°) were calculated by $[(a^*)^2\ (b^*)^2]^{½}$ and $\tan^{-1}(b^*/a^*)$.

Water solubility index (WSI) and water absorption index (WAI): WSI and WAI were determined according to the method described by Ahmed *et al.*[18]. The sample of 2.5 g and 30 mL of water were vigorously mixed in a 50 mL centrifuge tube. The mixture was incubated in a water bath at 30°C for 30 min and centrifuged at 2,000 rpm for 15 min. The supernatant was collected in a pre-weighed petri dish and the residue was weighed after being oven- dried overnight at 105°C. The amount of solids in the dried supernatant as a percentage of the total dry solids in the original 2.5 g sample were an indicator of the water solubility index. WAI was calculated as the weight of the solid pellet remaining after centrifugation divided by the amount of dry sample.

Swelling capacity (SWC): Swelling capacity was determined according to Ahmed *et al.*[18] using the Eq:

$$\text{SWC} = \frac{\text{Weight of the wet sediment (g)}}{\text{Weight of the dry powder (g)}}$$

Scanning electron microscopy (SEM): Powder granule morphology was examined by scanning electron microscopy which were measured according to the method reported by Peng *et al.*[19] A sample was mounted on the aluminum specimen holder with double-sided tape. The specimen holder was loaded in a JEOL JSM-5200 model (Tokyo, Japan). The sample was coated with gold palladium and the thickness was about 15 nm and was viewed under a scanning electron microscope (S-2400 Hitachi, Ibaraki, Japan) operated at an accelerating voltage of 10 kV.

Statistical analysis: Three sample replications were performed. Data were analyzed using one-way ANOVA and the least significant different procedures were done to separate means and differences reported as significant at $p \leq 0.05$ by using a standard statistical software package

RESULTS AND DISCUSSION

Effects of spray drying at different inlet air temperatures

Color: The Hunter color parameters L*, a*, b*, C* and h° values of HRBE powder produced at different inlet air temperatures are shown in Table 1. When the inlet air temperatures increased from 100 to 120°C and 140°C, the L*, b*, C* and h° of the HRBE powder were significantly increased. On the other hand, the a* decreased when increased air inlet temperatures. When dried temperatures increased from 100 to 140°C, color values of L*, b*, C* and h° also increased by 35.03, 37.62, 12 and 19%, respectively, while the color value of a* decreased by 7.5%. It indicated that the color of the powder became

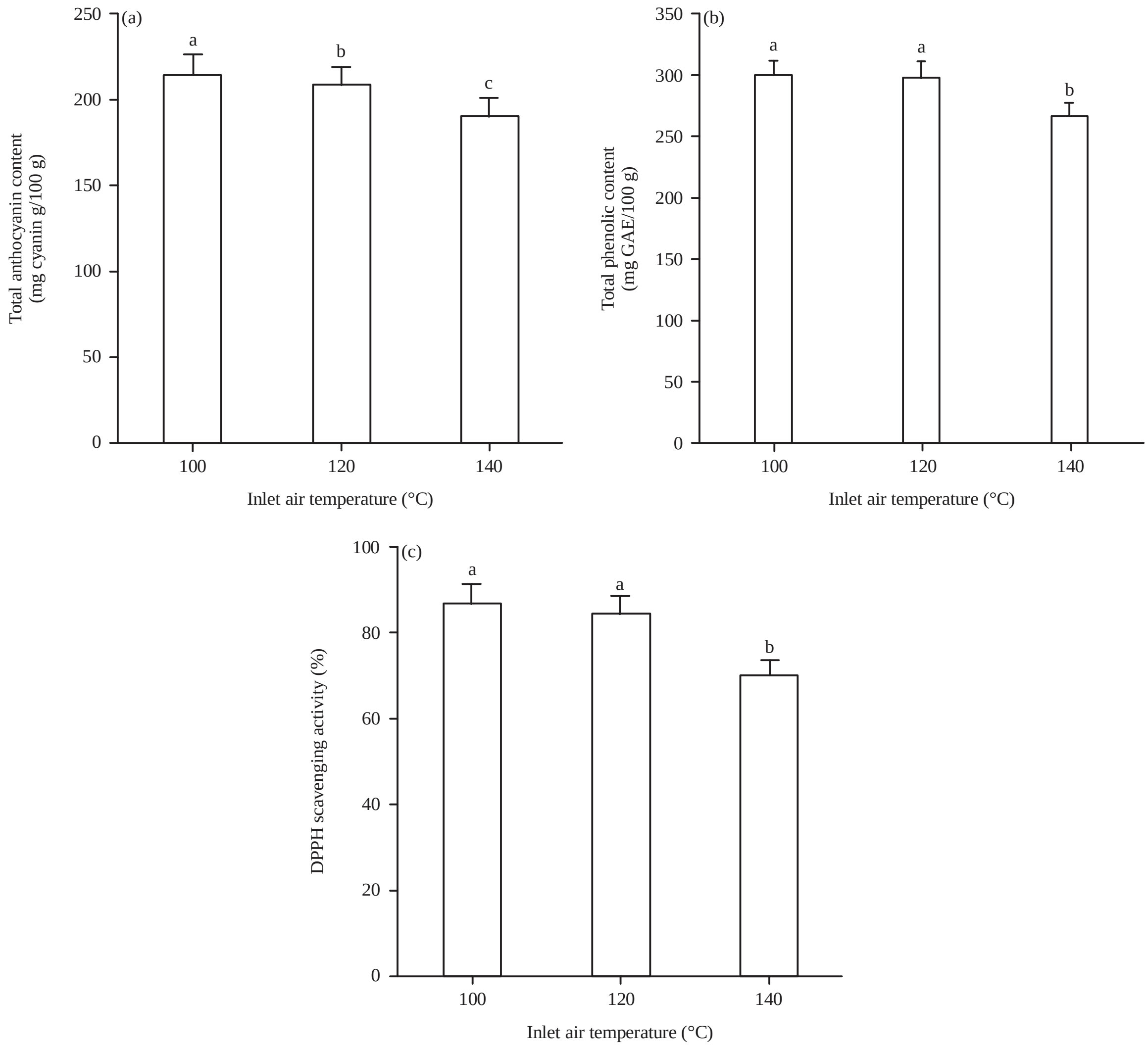

Fig. 1(a-c): Effect of different inlet air temperatures (°C) on total phenolic content (TPC), (a) Total anthocyanin content (TAC), (b) TPC and (c) DPPH assay of HRBE powder

Error bars indicate the standard error of the mean (n = 3). Mean bars with different letters (a-d) show significantly different ($p \leq 0.05$)

Table 1: Color values of spray-dried HRBE powder at various levels of inlet air temperature at feeding rate of 8.5 mL min^{-1}

inlet air temperature (°C)	Outlet air temperature (°C)	Color parameter				
		L*	a*	b*	C	h°
100	85	28.23±0.21^b	38.21±065^a	3.10±0.02^b	29.11±0.81^b	4.9±0.21^b
120	89	30.72±0.43^b	37.28±0.35^a	3.10±0.43^b	31.23±0.44^b	5.6±0.55^b
140	92	38.12±0.01^a	35.32±0.41^b	4.97±0.11^a	33.32±0.32^a	6.1±0.32^a

Means (standard deviation, n = 3) in the same column with different letters are significantly different ($p \leq 0.05$)

brighter at the higher inlet air temperatures. The changes of color values might be due to polymeric anthocyanin formation[19]. Ahmed *et al.*[18] also reported that the a* value of anthocyanin from purple sweet potato flour by spray drying was decreased when drying temperatures was increased. The probable reason may be that spray drying increased the surface area causing rapid pigment oxidation[20].

TPC, TAC and DPPH scavenging: The effects of the inlet air temperatures on the TPC, TAC and DPPH of HRBE powder are shown in Fig. 1. When the inlet air temperatures increased from 100 to 120°C and 140°C, the TPC, TAC and DPPH of the extracts significantly decreased. The results showed that the highest TPC, TAC and DPPH levels were observed in the sample dried at 100°C with the values of 305.02 mg gallic acid

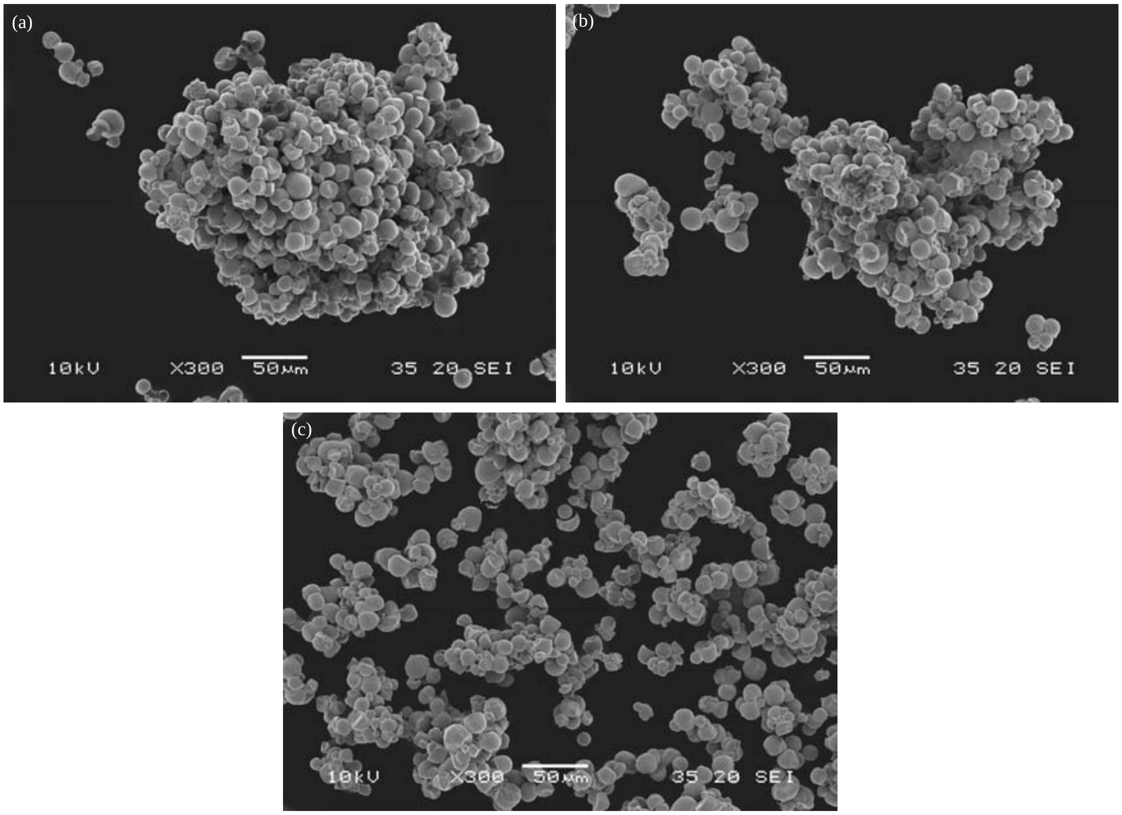

Fig. 2(a-c): Scanning electron microstructure of spray-dried HRBE obtained at inlet air temperature of (a) 100°C, (b) 120°C and (c) 140°C feeding rate of 8.5 mL min^{-1}

Table 2: Water absorption index (WAI), water-soluble index (WSI) and swelling capacity (SWC) of spray-dried HRBE at different inlet air temperatures

Inlet air temperature (°C)	Parameters		
	WAI (g/g dry solids)	WSI (g/100 g dry solids)	SWC (g/g dry solids)
100	0.92 ± 0.03^{a}	50.21 ± 0.87^{b}	2.53 ± 0.76^{b}
120	1.06 ± 0.54^{a}	57.34 ± 0.88^{a}	2.90 ± 0.20^{a}
140	1.19 ± 0.21^{a}	59.25 ± 0.56^{a}	2.94 ± 0.33^{a}

Means (standard deviation, n = 3) in the same column with different letters are significantly different ($p\leq0.05$)

equivalent (GAE)/100 g, 215.12 mg cyanidin/100 g and 86.14%, respectively, which were higher than those of the other inlet air temperatures ($p\leq0.05$). The possible explanation for the loss of TPC, TAC and DPPH may be because of the exposure to higher temperatures which adversely affected the structure of phenolics. This was the cause of its break down and/or formation into different forms. Similar results were observed in spray dried blackberry powder reported by Ferrari *et al.*[21] In addition, inlet temperatures affected the stability of anthocyanin in the acai juice powder[22]. When the inlet air temperatures increased, the anthocyanin content in the acai juice powder decreased.

Water solubility index (WSI) and water absorption index (WAI) and swelling capacity (SWC) of HRBE powder: The effects of the inlet air temperatures on the WSI, WAI and SWC are shown in Table 2. When the air inlet temperatures increased from 100 to 120°C and 140°C, WSI, WAI and SWC of the HRBE powder were not significantly increased. The WSI of samples were not influenced by the different drying temperatures ($p>0.05$). The range of WSI, WAI and SWC of the samples was 50.21-59.25, 0.92-1.19 and 2.53-2.94%, respectively. The variation in WSI, WAI and SWC could be due to differences in the degree of engagement of hydroxyl groups to form hydrogen and covalent bonds between starch chains. The higher inlet air temperatures caused an increase in the process yield and solubility.

Scanning electron microscopy (SEM): The effects of inlet air temperatures on the SEM of HRBE powder are shown in Fig. 2.

When drying at lower temperatures (100°C, Fig. 2a), a degree of shrinkage is less than those drying at a higher temperatures (120 and 140°C, Fig. 2b, c). The sizes of the HRBE powder were in the range 3-50 μm. By comparing the particles produced at different drying temperatures, it can be seen that lower drying temperature led to relatively uniform size and shape with smooth particle surface. Whereas, higher drying temperature resulted in size variations and wrinkled particle surfaces[10]. SEM studies revealed that the average size of particles in the dried powder at a higher inlet air temperature was smaller than that dried at a lower inlet temperature.

The use of lower inlet air temperature also led to larger particles of spray dried acai powder as reported by Tonon *et al.*[11].

CONCLUSION

The TPC, TAC and DPPH scavenging activity of HRBE powder that spray dried with 10 DE maltodextrin at 100°C were 305.12 mg gallic acid equivalent (GAE)/100 g, 215 mg cyanidin/100 g and 86.14%, respectively, which were higher than those of the other inlet air temperatures ($p \leq 0.05$). The, L*, a*and b* values were 28.23, 38.21 and 3.10, respectively. The range of WSI of samples was 50.21-59.25%. The sizes of the powder were in the range of 3-50 μm. HRBE powder could be prepared by spray drying with 10 DE maltodextrin at the inlet air temperature of 100°C. The obtained samples showed lower degradation of total anthocyanins and total phenolics and low loss of antioxidant activity and total color difference.

SIGNIFICANCE STATEMENT

This study discovers the influence of spray drying at different inlet air temperatures on the antioxidant activity and some properties of HRBE powder that can be beneficial for use as bioactive food ingredients and it has a high potential. This study will help the researcher to uncover the critical areas of properties of HRBE powder after spray drying that many researchers were not able to explore. Thus, a new theory on properties of HRBE powder may be arrived at.

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