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Effect of high-temperature fluidized bed drying on quality of 'Kum Doi Saket' variety of purple rice

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Abstract

The objective of this study was to investigate the effects of high-temperature drying in a range of 100-150 °C using fluidization technique on quality changes of 'Kum Doi Saket' indigenous purple rice variety in Thailand. Experimental results revealed that using high temperature process reduced free fatty acid content (FFA) in kernel without any effects on kernel colour, anthocyanins and antioxidant content. A higher process temperature resulted in a better quality of brown rice in terms of FFA. Moreover, it was found that the antioxidant activity of purple rice subjected to various drying conditions and tested by 2,2-diphenyl-1-picrylhydrazyl radical assay (DPPH) technique showed no significant difference with the reference purple rice. As for FFA level, it significantly decreased when the samples were dried at temperatures of 130 and 150 °C. The present study found that within the range of parameters studied, the purple rice harvested at 28.3% (d.b.) moisture content of dried at 150 °C for 1.5 minutes was of the best quality. This drying temperature did not affect the anthocyanin content nor the antioxidant activity of purple rice and had the highest drying rate.

Introduction

Purple rice is characterised by high antioxidant activity due to the presence of bran. The colour characteristic of the bran is red or purple due to the presence of several anthocyanins (Abdel-Aal *et al*., 2006; Jang and Xu, 2009; Yodmanee *et al*., 2011; Min *et al*., 2012). The significant characteristic of anthocyanins is their antioxidant activity which is a desirable aspect for consumer who is interested in health. Many studies reported about usefulness of anthocyanins that can inhibit cancer cells of internal organs in humans such as lungs, stomach and colon (Kang *et al*., 2003; Chen *et al*., 2006a; Chen *et al*., 2006b; Netzel *et al*., 2007; Wang and Stoner, 2008; Yun *et al*., 2010; Huang *et al*., 2011).

After harvesting, rice generally requires in order to ensure its safe storage. Drying in a fluidized bed dryer at high-temperature is one of possible methods that could effectively be used to dry purple rice. In a fluidized bed dryer, the solid particles are behaving like a fluid and vigorously mix with the drying medium (air) at high temperatures. As a result, the drying time is shortened due to intensive heat and mass transfer (Mujumdar and Devahastin, 2003).

In addition, Jaisut *et al.* (2009) reported that lipase and unsaturated free fatty acid were inactivated and degraded in dried brown rice by high temperature air during fluidization. As a result, the rate of lipid oxidation slowed down and free fatty acid content was reduced resulting in a significant reduction in rancidity and hence extension of the shelf-life of brown rice. Although drying by fluidization technique has many advantages as mentioned earlier, using a thermal process might affect colour, produce degradation of anthocyanins and reduce antioxidant activity of the samples (Yang *et al*., 2008; Avila *et al*., 2012; Chaovanalikit *et al*., 2012; Hou *et al*., 2013; Kara and Erçelebi, 2013; Nurhuda *et al*., 2013; Rabeta and Vithyia, 2013; Sengkhamparn *et al*., 2013)

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Until now, the effects of high-temperature drying using fluidization technique on quality changes of brown purple rice have not been reported and thus this research is needed. The objective of this work is therefore to investigate the effects of drying temperature on the drying kinetics and key quality attributes of brown purple rice. The quality parameters were the colour, anthocyanin content, antioxidant activity and free fatty acid content.

Materials and Methods

Materials

Purple rice 'Kum Doi Saket' variety that was obtained from the Plant Science and Natural Resources Department, Faculty of Agriculture, Chiang Mai University, Thailand in 2013 was used in this study. The paddy sample was rewetted from the initial moisture content of 13-15% (d.b.) at the time of harvest to the moisture content of 28.3% (d.b.) by spraying water and kept in cold store at 4-6 ^{o}C for a week. Before starting the experiment, sample was taken out from the cool storage and left for a given period of time in the laboratory in order to allow the grain temperature to reach the ambient temperature.

Experimental set-up

A fluidized bed drying system consisted of a 12 kW electrical heater controlled by a PID controller with an accuracy of ±1 ^{o}C, a cylindrical drying chamber with diameter of 20 cm and a backward-curved blade centrifugal blower driven by a 1.5 kW motor.

Dried sample preparation

Rewetted paddy sample (2 kg) was dried in a fluidized bed dryer at temperatures of 100-150 ^{o}C (HA) with a bed depth of 0.1 m and at a superficial air velocity of 3.0 m/s. The exhaust air was recycled to the tune of 78%. During the drying operation, samples were taken out from the drying chamber at 22.0% (d.b.) and tempered in a closed jar for 30 minutes to relax the moisture-induced stresses which occurred during drying. Finally, the dried sample was ventilated with ambient air for 30 min until the sample moisture content reached 13-15% (d.b.).

Colour determination

CIELAB parameters were used for measuring brown rice samples (3 replicates) using a colorimeter (Minolta model CR 400, Japan). The results are expressed as lightness *(L^*)*, red *(a^*)*, blue *(b^*)*, and hue angle values.

Extraction of brown rice samples

Brown rice samples (10 g) were homogenized with 99.9% methanol and then incubated under constant stirring for 2 h. After that, the samples were filtered through Whatman paper No. 1. The methanol extract was collected in plastic vials for analysis of total phenolics, total anthocyanin content, and antioxidant activity.

Total anthocyanin content

Total anthocyanin content in the methanol extract from brown rice sample was determined according to Giusti and Wrolstad (2005). Potassium chloride buffer (0.025 M KCl, pH 1.0) was used in this analysis. A mixture of 900 µL of pH 1.0 and 100 µL of extracted samples was incubated for 15 min at room temperature (25 °C) and then measured by spectrum scanning (320-700 nm) with a UV-visible spectrophotometer (Shimadzu model 1800, Japan). The absorbance of the diluted sample was calculated as shown in equation (1).

$$A = (A_{\lambda vis\text{-}max} - A_{700})_{pH\ 1.0} \quad (1)$$

Anthocyanin pigment concentration in the sample was calculated using equation (2)

$$\text{anthocyaninpigment(mg/L)} = (A \times MW \times DF \times 1000)/(\varepsilon \times 1) \quad (2)$$

where cyanidin-3-glucoside molecular weight (MW = 449.2), Dilution factor (DF), and the molar absorptive constant (ε = 26,900) were used.

Antioxidant activity determination

Free radical-scavenging activity of extracts was assessed using the 1,1-diphenyl-2-picrylhydrazyl radical (DPPH) method which was modified from Brand-Williams *et al.* (1995). Twenty four milligrams of DPPH were dissolved in 100 mL of methanol as the stock solution. Then working solution was prepared from the stock solution by mixing 10 mL of stock solution with 45 mL of methanol. After that, measurement of working solution was carried out using a spectrophotometer at 515 nm to obtain an absorbance of 1.1±0.02 units. Following that, the brown rice extracts (150 µL) were made to react with 2.85 mL of working solution for 30 min in the dark. Then, the absorbance (Abs) at 515 nm was recorded. The antioxidant activity of the samples was calculated using equation (3).

$$\%\ \text{inhibition} = [(Abs_{control} - Abs_{sample})/Abs_{control}] \times 100 \quad (3)$$

Free fatty acid content

Free fatty acid content (FFA) of samples was determined according to the AACC Official Method with some modification (AACC, 1995). Ten grams of ground brown rice were extracted with 200 mL of petroleum ether by shaking at 100 rpm for 16 h. Extracted samples were then filtered through Whatman paper No. 1. The samples were evaporated at 70 °C on a hot plate. The purple rice extract was dissolved with 50 mL of alcohol-phenolphthalein (95% ethanol and 0.4 g of phenolphthalein). Finally, aqueous rice sample was titrated with 0.0178 N KOH. The titration was finished when the solution mixture turned to a faint pink colour. The FFA content was expressed as the percentage of oleic acid and calculated using equation (4).

$$\text{FFA}\left(\frac{\text{mg KOH}}{\text{100 g dry mater}}\right) = \left(\frac{\text{10 x (mL KOH used)} - \text{(mL KOH blank)x100}}{\text{100} - \text{(g water in 100 g sample}}\right) \quad (4)$$

Results and Discussion

Physical characteristics of brown rice

Initial moisture content of paddy after rewetting was at 28.3% (d.b.) which was rapidly decreased during the first 30 s of the process at all drying temperatures (Figure 1).

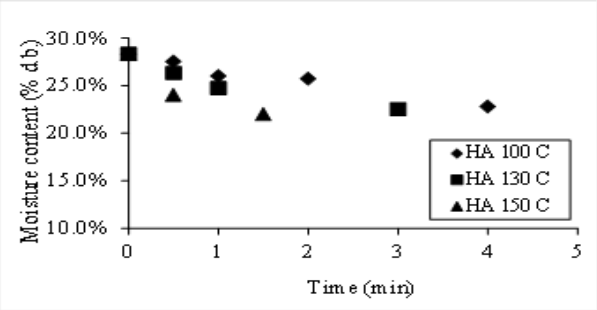

Figure 1. Changes in moisture content of paddy during hot air drying at temperatures between 100 -150 °C.

This was due to the fact that moisture content of the paddy surface was initially high, resulting in high drying rates when heat was transferred. The drying rate has then decreased slowly as the drying progressed, depending on the drying temperature. The higher drying temperature, the higher rate of moisture removal from paddy because of the higher grain temperature (Figure 2).

At the end of the drying process, the grain temperature of hot air (HA), i.e. 100, 130 and 150 °C, dried samples at was 62, 74 and 80 °C, respectively. A higher grain temperature accelerated the moisture movement from inside the kernel to the external surface at a higher rate. The highest grain temperature for the same drying time drying air temperature of 150°C), resulted in the highest drying rate and the corresponding shortest drying time. The drying times required for sample drying from initial moisture content to desired moisture content of 22.0% (d.b.) at drying air temperature of 100, 130 and 150°C were 1.5, 3 and 4 min, respectively.

Table 1. Colour assessment of brown rice samples from paddy dried at different drying air temperatures

Drying media	Temperature (°C)	*L**	*a**	*b**	hue angle
Reference purple rice (control)	-	22.1 ± 1.0	9.1 ± 1.6	1.7 ± 1.3	7.9 ± 3.4
Hot air	100	22.3 ± 1.5	10.0 ± 0.8	1.9 ± 1.1	10.5 ± 1.8
	130	24.1 ± 2.2	9.2 ± 0.8	1.3 ± 0.9	8.0 ± 2.2
	150	23.5 ± 0.6	9.8 ± 1.4	1.3 ± 0.7	9.3 ± 0.2
		ns	ns	ns	ns

The values in each column are not significantly different at $p < 0.05$

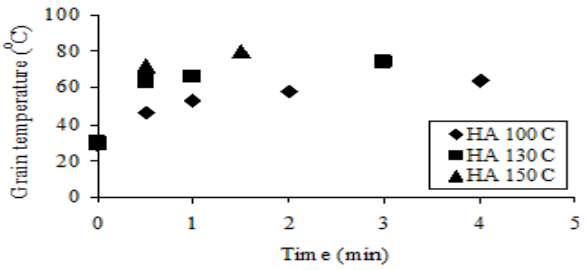

Figure 2. Changes in grain temperature of paddy during hot air drying at temperatures between 100 -150 °C

Colour assessment

Table 1 shows surface colour of brown rice which was produced by milling paddy dried at various temperatures, compared to non-treated control. Although several studies reported the effects of thermal process on colour pigments of rice samples (Yang *et al.*, 2008; Kara and Erçelebi, 2013; Nurhuda *et al.*, 2013; Sengkhamparn *et al.*, 2013), the results of this study revealed that the colour represented by L^* $a,^*$ b^* and hue angle of reference sample (non-treated control) and dried samples were not significantly different. This might be because the residence time in the fluidized bed dryer used in the experiments was very short and thus preserved the quality of milled rice. Therefore, the reaction time that could trigger the colour change of milled rice was not long enough. An increase of the drying temperature has not affected the colour change of purple rice after drying.

Table 2. Anthocyanin content and antioxidant activity of brown rice from paddy dried at different drying air temperatures

Drying media	Temperature (°C)	Anthocyanin content (mg/100g FW)	DPPH activity (% Inhibition)
Reference purple rice (control)	-	4.6 ± 0.1	93.1 ± 1.2
Hot air	100	4.4 ± 0.2	92.3 ± 0.4
	130	4.5 ± 0.0	92.5 ± 0.8
	150	4.3 ± 0.2	92.0 ± 0.5
		ns	ns

The values in each column are not significantly different at $p < 0.05$

Changes in bioactive compounds in purple rice

Total anthocyanin content

Total anthocyanin content of kernels dried at various temperatures is shown in Table 2. Milled rice samples of 'Kum Doi Saket' dried at different temperatures contains anthocyanins in the range of 4.3-4.6 mg/100 g fresh weight (FW) without significant difference between treatments. The contents were well correlated with the colour characteristics of samples due to anthocyanin pigment (Yang *et al*., 2008; Kara and Erçelebi, 2013).

Antioxidant activity

The antioxidant activity detected by DPPH method was reported as percent inhibition. The activity of all dried samples was in a range of 92.0-93.1% (Table 2). As expected, because anthocyanins are the main antioxidant in purple rice the antioxidant activity of the reference sample and in all dried samples showed no significant difference because of non-degraded anthocyanins.

Free fatty acid content

The free fatty acid content (FFA) of samples dried by HA at 100 °C was not significantly different value as compared to the reference rice because the grain temperature at this drying air temperature might not be high enough for inhibit enzymatic oxidation in comparison with higher temperature (Figure 3). The oxidation of polyunsaturated fatty acids of brown rice had occurred in the bran of paddy samples dried at higher temperature. The free fatty acid content of 100 °C dried rice was higher than in the samples subjected to other treatments. When the drying temperature was higher than 100 °C, the FFA content of dried samples decreased, especially at 150 °C drying air temperature. The reducing FFA was mostly degraded by heat in unsaturated free fatty acids (Lu and Tan, 2009; Meera *et al*., 2011).The high drying air temperature in a fluidized bed dryer reduces FFA in rice bran by without any effect on the other quality attributes of purple rice such as colour, anthocyanins, and antioxidant activity.

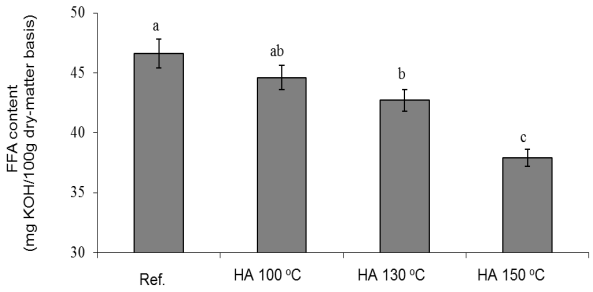

Figure 3. Free fatty acid content (FFA) of paddy dried at temperatures between 100 – 150 °C
Different letters over each bar indicate significant difference at $p < 0.05$

Conclusions

The purple paddy rice harvested at a moisture content of 28.3% (d.b.) should be dried by HA at 150°C. At this drying temperature, the FFA content of samples was markedly reduced and the drying rate had the highest value. Within the range of drying temperatures studied, drying in a fluidized bed dryer did not affect colour, anthocyanin content or antioxidant activity of purple rice.

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References

AACC. 1995. Approved methods of the American Association of Cereal Chemists. St. Paul, MN: AACC.

Abdel-Aal, S. M., Young, J. C. and Rabalski, I. 2006. Anthocyanin composition in black, blue, pink, purple, and red cereal grains. Journal of Agricultural and Food Chemistry 54: 4696-4704.

Avila, P. A., Namiesnik, J., Toledo, F., Werner, E., Martinez-Ayala, A. L., Rocha-Guzmán, N. E., Gallegos-Infante, J. A. and Gorinstein, S. 2012. The influence of different time durations of thermal processing on berries quality. Food Control 26: 587-593.

Brand-Williams, W. M., Cuvelier, E. and Berset, C. 1995. Use of a free radical method to evaluate antioxidant activity. Lebensmittel Wissenschaft und Technologie/ Food Science and Technology 28: 25-30.

Chaovanalikit, A., Mingmuang, A., Kitbunluewit, T., Choldumrongkool, N., Sondee, J. and Chupratum, S. 2012. Anthocyanin and total phenolics content of mangosteen and effect of processing on the quality of mangosteen products. International Food Research Journal 19 (3): 1047-1053.

Chen, P. N., Chu, S. C., Chiou, H. L., Kuo, W. H., Chiang, C. L. and Hsien, Y. S. 2006a. Mulberry anthocyanins, cyanidin 3-rutinoside and cyanidin 3-glucoside, exhibited an inhibitory effect on the migration and invasion of a human lung cancer cell line. Cancer Letters 235: 248-259.

Chen, P. N., Kuo, W. H., Chiang, C. L., Chiou, H. L., Hsien, Y. S. and Chu, S. C. 2006b. Black rice anthocyanins inhibit cancer cells invasion via repressions of MMPs and u-PA expression. Chemico-Biological Interactions 163: 218-229.

Ghinea, R., Ugarte-Alvan, L., Yebra, A., Pecho, O.E., Paravina, R.D., Perez, M.M., 2011. Influence of surface roughness on the color of dental-resin composites. Journal of Zhejiang University-SCIENCE B (Biomedicine & Biotechnology) 12, 552-562.

Giusti, M. M. and Wrolstad, R. E. 2005. Characterization and measurement of anthocyanins by UV-visible spectroscopy. In Wrolstad, R. E., Acree,T. E., Decker, E. A., Penner, M. H., Reid, D. S., Schwartz, S. J., Shoemaker, C.F., Smith, D. and Sporns, P. (Eds). Handbook of Food Analyical Chemistry (Vol. 2): Pigments, Colorants, Flavors, Texture, and Bioactive Food Components, p. 19-31. New Jersey: John Wiley & Sons Inc.

Hou, Z., Qin, P., Zhang, Y., Cui, S. and Ren, G. 2013. Identification of anthocyanins isolated from black rice (*Oryza sativa* L.) and their degradation kinetics. Food Research International 50: 691-697

Huang, H. P., Chang, Y. C., Wu, C. H., Hung, C. N. and Wang, C. J. 2011. Anthocyanin-rich mulberry extract inhibit the gastric cancer cell growth in vitro and xenograft mice by inducing signals of p38/p53 and c-jun. Food Chemistry 129: 1703-1709.

Jaisut, D., Prachayawarakorn, S., Varanyanond, W., Tungtrakul, P. and Soponronnarit, S. 2009. Accelerated aging of jasmine brown rice by high-temperature fluidization technique. Food Research International 42: 674-681.

Jang, S. and Xu, Z. 2009. Lipophilic and hydrophilic antioxidants and their antioxidant activities in purple rice bran. Journal of Agricultural and Food Chemistry 57: 858-862.

Kang, S. Y., Seeram, N. P., Nair, M. G. and Bourquin, L. D. 2003. Tart cherry anthocyanins inhibit tumor development in ApcMin mice and reduce proliferation of human colon cancer cells. Cancer Letters. 194: 13-19.

Kara. Ş. and Erçelebi, E. A. 2013. Thermal degradation kinetics of anthocyanins and visual colour of Urmu mulberry (*Morus nigra* L.). Journal of Food Engineering 116: 541-547.

Lu, H. F. S. and Tan, P. P. 2009. A Comparative study of storage stability in virgin coconut oil and extra virgin Olive oil upon thermal treatment. International Food Research Journal 16: 343-354.

Meera, M. S., Bhashyam, M. K. and Ali, S. Z. 2011. Effect of heat treatment of sorghum grains on storage stability of flour. LWT - Food Science and Technology 44: 2199-2204.

Min, B., Gu, L., McClung, A. M., Bergman, C. J., Chen, M. 2012. Free and bound total phenolic concentrations, antioxidant capacities, and profiles of proanthocyanidins and anthocyanins in whole grain rice (*Oryza sativa* L.) of different bran colours. Food Chemistry 133: 715-722.

Mujumdar, S. and Devahastin, S. 2003. Applications for fluidized bed drying, In Yang, W. C. (Ed). Handbook of fluidization and fluid-particle systems. chapter 18. NEW YORK: Taylor & Francis Group LLC.

Netzel, M., Netzel, G., Kammerer, D. R., Schieber, A., Carle, R., Simons, L., Bitsch, I., Bitsch, R. and Konczak, I. 2007. Cancer cell antiproliferation activity and metabolism of black carrot anthocyanins. Innovative Food Science and Emerging Technologies 8: 365-372.

Nurhuda, H. H., Maskat, M. Y., Mamot, S., Afiq, J. and Aminah, A. 2013. Effect of blanching on enzyme and antioxidant activities of rambutan *(Nephelium lappaceum)* peel. International Food Research Journal 20 (4) : 1725-1730.

Rabeta, M. S. and Vithyia, M. 2013. Effect of different drying methods on the antioxidant properties of *Vitex negundo* Linn. tea. International Food Research Journal 20(6): 3171-3176.

Sengkhamparn, N., Chanshotikul, N., Assawajitpukdee, C. and Khamjae, T. 2013. Effects of blanching and drying on fiber rich powder from pitaya *(Hylocereus undatus)* peel. International Food Research Journal 20 (4) : 1595-1600.

Wang, L. S. and Stoner, G. D. 2008. Anthocyanins and their role in cancer prevention. Cancer Letters 269: 281-290.

Yang, Z., Han, Y., Gu, Z., Fan, G., Chen, Z. 2008. Thermal degradation kinetics of aqueous anthocyanins and visual color of purple corn (*Zea mays* L.) cob. Innovative Food Science and Emerging Technologies 9: 341-347.

Yodmanee, S., Karrila, T. T. and Pakdeechanuan, P. 2011. Physical, chemical and antioxidant properties of pigmented rice grown in Southern Thailand. International Food Research Journal 18 (3) : 901-906.

Yun, J. W., Lee, W. S., Kim, M. J., Lu, J. N., Kang, M. H., Kim, H. G., Kim, D. C., Choi, E. J., Choi, J. Y., Kim, H. G., Lee, Y. K., RYU, C. H., Kim, G., Choi, Y. H., Park, O. J. and Shin, S. C. 2010. Characterization of a profile of the anthocyanins isolated from Vitis coignetiae Pulliat and their anti-invasive activity on HT-29 human colon cancer cells. Food and Chemical Toxicology 48: 903-909.