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Microwave drying of cooked brown rice and the effect on the nutrient composition and trace elements

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Abstract

The objective of this work was to study the effect of a new low temperature drying system by continuous and instant microwave power control on cooked brown rice. The drying system was operated in the microwave power range of 280 W to 320 W. Samples of cooked brown rice (4 cm diameter x 1 cm high) were used. The optimum drying was at 300 W for 48 min. The changes in the nutrient composition and trace elements of the cooked brown rice, resulting from before and after microwave drying at 300 W for 48 min, were then analyzed. No change of crude protein, ash, crude fiber, and carbohydrate was observed in the cooked brown rice both before and after drying ($P>0.05$) though a little crude fat change was found ($P>0.05$). Simultaneously, no explicit changes were found regarding the potassium (K), magnesium (Mg), and zinc (Zn) levels after the drying ($P>0.05$). It is demonstrated that by this drying method brown rice retained its fresh nutritional value and mineral content.

Introduction

Traditionally, dried brown rice is sun dried for 1 - 3 days to substantially reduce water content. Although the sun drying method is cheap, there is a risk of damage due to dust, microorganisms, insect infection, poor color, and loss of nutrition (Ergüneş and Tarhan, 2006; Esper and Mühlbauer, 1998). An alternative to this is artificial drying. Microwave drying is a technique that allows dehydration and can be applied to certain types of rice (Zhao *et al*., 2007) and starchy food (Khraisheh *et al*., 2004). The advantage in microwave technology is the high wave penetration capacity in which heat can penetrate inside the product. Therefore, the microwave drying process can improve the quality of the final product compared to other dehydration techniques (Wu and Mao, 2008; Kassem *et al*., 2011). In this work, phase controlled microwave power has been developed for continuous and instant microwave power output. Since the powers are instant, therefore appropriate drying temperature of the rice can be obtained for high quality of the dried products (Cheng *et al*., 2006; Li *et al*., 2011)

Brown rice has become a popular health food. Consumption of brown rice has been associated with decreased waist circumference in patients with type 2 diabetes because it is rich in dietary fiber, vitamins, minerals, and other unmeasured dietary constituents (Choe *et al*., 2011). Moreover, brown rice contains large amounts of insoluble fiber which may prevent a variety of cancers (Li *et al*., 2011). Fresh brown rice, which has a lot of nutritional value, needs to be stored at low moisture content after postharvest. Storage can induce the deterioration of rice quality through microorganisms, rodents, and insects (Genkawa *et al*., 2008). In addition, cooked rice is an important main food for everyone throughout the world. Therefore, processing fresh cooked brown rice by drying it is one of the alternative methods to extend the shelf life and improve the quality. The objectives of this study were to evaluate the efficacy of low temperature microwave drying for cooked brown rice and to investigate the effect of microwave drying on the nutrient composition and trace elements of cooked brown rice

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Materials and Methods

Brown rice samples

Brown rice (Sangyod Muang Phatthalung rice) was selected for the study and it was purchased from the Mai Bang Pakdee Raom Jai Agricultural Cooperative Society Ltd., a local rice milling factory in the Phatthalung province, Thailand.

Production of cooked brown rice

Experiments were conducted with an automatic rice cooker (SR-DG 182, 1.8L, 600 W, 220 V, 50 Hz, Panasonic Management Co., Ltd. Thailand). Two hundred grams of brown rice were soaked in a pot for 10 min with 300 ml of deionized water. After the rice was cooked for 60 min, a thermostat coupled with a microswitch automatically switched off the rice cooker. Then the cooked brown rice was moved from the rice cooker to a stainless template (4 cm diameter x 1 cm high). All samples were placed on a stainless tray for 30 min at 30^{o}C before microwave drying.

Microwave drying

Microwave drying was performed in a power adjustable microwave oven developed by the Plasma Agricultural Application Laboratory of Walailak University as seen in Figure 1. The oven can be operated at microwave output powers of 280 W, 300 W and 320 W. Fan speed in the air oven were at 1 meter per second. The volume in which each drying was conducted was 330 mm × 450 mm × 300 mm in size and consisted of a rotating glass plate with a 240 mm diameter at the base of the oven. For about 5 min the glass plate rotated at 360° in which the rotation could be changed by pressing the on/off button. Time adjustment was done with the aid of a digital clock. After cooling the cooked brown rice (4 cm diameter × 1 cm high) at room temperature, it was put in the microwave oven. The rice was removed from the oven periodically (every 5 min) during the drying period, and the moisture loss was determined by AOAC (2005).

Measurement of the color of the dried brown rice

The color of the dried brown rice after drying at 280 W for 70 min, 300 W for 48 min and 320 W for 32 min was measured using a color analyzer and a 9-point hedonic scale. The color analyzer (MiniScan EZ, Hunter Associates Laboratory Inc., USA) was used to measure the degree of lightness (L*), redness-greenness (+ or − a*), and yellowness-blueness (+ or − b*). Each dried brown rice sample (4g) was placed into a clear Petri dish (4 diameters). Each value represents the mean of 8 samples.

A 9-point hedonic scale ranging from "like extremely" to "dislike extremely" was used to determine the degree of color acceptance for the dried brown rice (4 cm diameter x 1 cm high) in terms of color liking. Consumer panels who normally eat rice everyday (46 peoples) were selected among Walailak University's students and staff, Thailand. The consumer panels evaluated three dried brown rice samples at 280 W for 70 min, 300 W for 48 minutes and 320 W for 32 min in a control room. The responses were converted to numerical values ranging from 1 for "dislike extremely" to 9 for "like extremely."

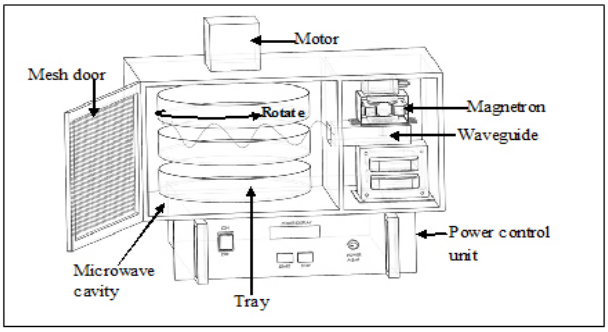

Figure 1. Schematic diagram of the controlled microwave oven

Determination of proximate composition

The proximate composition of cooked brown rice both before and after microwave drying at 300 W for 48 min was prepared by grinding it (Philips, Thailand). Analysis for moisture, crude fat, total ash, crude fiber, and crude protein was as prescribed in the official methods of analysis (AOAC, 2005). For the moisture content determination, the sample was dried at 105°C until there was a constant weight and then it was cooled and weighed. The weight loss as it was dried to a final constant weight was used to calculate moisture content. For the crude fat assay, the dried sample was extracted in a Soxhlet-type extractor with petroleum ether (boiling point 60 – 80°C). The extract was dried for 30 min at 100°C and then cooled and the residual fat was weighed. Crude fiber was determined after digesting a known weight of a fat-free sample in refluxing 1.25% sulphuric acid and 1.25% sodium hydroxide. Crude protein determination was done by rapid distillation and titration of Kjeldahl acid digest samples. Total ash content determination was found by weighing residual ash obtained on the igniting of a prepared sample in a Muffle furnace at 550°C. Carbohydrate content was determined by difference. All determinations were carried out in triplicate and reported on dry matter.

Elemental analysis

Elemental analysis was measured by using inductively coupled plasma optical emission spectrometry (ICP-OES) using PerkinElmer's Optima 3300 DV model (Norwalk, CT, USA) with argon gas induced to coupled plasma. Both before and after microwave drying at 300 W for 48 min, the cooked brown rice was digested in triplicate. Two hundred mg of the sample was placed in the vessel and 5 mL of concentrated HNO_3 was added and maintained overnight. Then, 1mL of H_2O_2 was added. The digestion program was as follows: the temperature started at 100°C for 10 min and then was increased to 150°C for 10 min and then to 250°C for 30 min. The digestion completed in about 60 minutes as indicated by the appearance of transparent liquid mixture. The wet digested solution was transferred to plastic bottles that were accurately labelled and then stored in the refrigerator to later be used for elemental determination. (Modified from Heinemann *et al*., 2005)

Statistical analyses

All variables were tested for normality by applying the Kolmogorov – Smirnov test and the homogeneity of variances was assessed using Levene's test. Data transformation was done where necessary. All results were expressed as mean ± standard deviation. The data was statistically treated by ANOVA and Duncan's post hoc test and paired samples t-test with $p \leq 0.05$ considered to be statistically significant.

Results and Discussion

Microwave drying

The drying curves of the brown rice specimens having initial moisture content of 65% to the different final moisture content (12%) after 70, 48, and 32 min of drying time at various powers of microwave radiation (280, 300, and 320 W) are shown in Figure 2. Higher power of microwave radiation had more effective on the drying time of the specimens. To obtain 12% of moisture content, it will take only 48 min by 300 W of microwave radiation. The decreased moisture content could be attributed to increased evaporation of water both on the surface of and in the brown rice specimens. Effect of the microwave power on the moisture content of the brown rice was significant ($p \leq 0.05$). The microwave technique has been also reported by many authors to enhance the drying time of various food products and this drying method has been applied successfully to waxy and non waxy rice, coriander and potatoes (Anderson and Guraya, 2006; Zhang *et al*., 2006).

The drying rate for brown rice specimens at 280 W, 300 W, and 320 W is presented in Figure 3. At the starting time (Time ≥ 0), drying rates were higher for

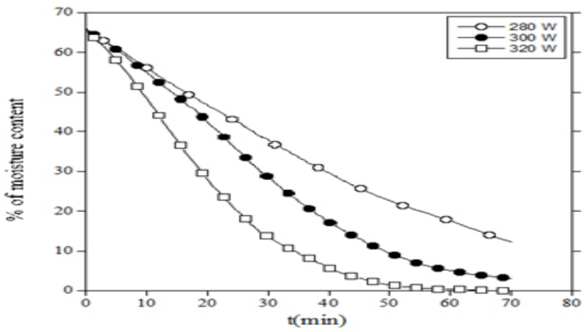

Figure 2. The microwave drying curves of cooked brown rice at 280 W, 300 W, and 320 W

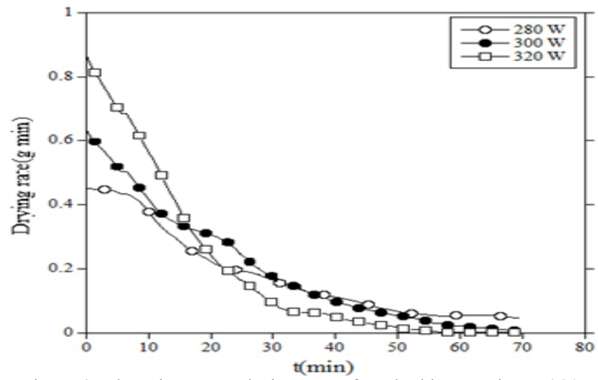

Figure 3. The microwave drying rate of cooked brown rice at 280 W, 300 W, and 320 W

higher microwave power because higher microwave power can generate heat and water pressure inside the brown rice more effectively (Datta and Anantheswaran, 2001). Since the loss tangent of the specimens decrease with their water content, the drying rates were decreased with time. After 40 min, drying rate of 280 W is higher than those of 300 W and 320 W. The falling period of drying rates were observed for each microwave power. It had been reported that the microwave drying rate can be divided into three stages: increasing at first, then constant, and falling at the end (Datta and Anantheswaran, 2001). In our case, the increasing and constant drying rates were very short for all powers. These might be caused by the effectiveness of microwave power absorption by the specimens.

Color analysis and color acceptance

The average values of the three chromatic scales (L*, a*, b*) measured and the color acceptance by sensory test for both fresh and dried brown rice are given in Table 1. While the L* and a* value of fresh cooked brown rice was significantly higher than the dried samples at high power and short time (320W, 32 min), the b* value was considerably lower than that of dried brown rice ($p \leq 0.05$). It is clear that the color of cooked brown rice changed substantially during microwave drying. Specifically, high microwave power and short time (320W, 32 min) resulted in lower

Table 1. Microwave drying for color parameters after cooked brown rice drying

Sample	L*	a*	b*	Color liking
Fresh cooked brown rice	30.14 ± 1.71^{a}	7.63 ± 0.98^{a}	9.11 ± 0.61^{ab}	7.1 ± 0.7^{ab}
Dried brown rice				
280 W, 70 min	29.01 ± 0.54^{a}	6.56 ± 0.34^{b}	19.12 ± 0.47^{ab}	6.8 ± 1.1^{ab}
300 W, 48 min	30.50 ± 0.35^{a}	8.54 ± 0.21^{a}	16.49 ± 1.08^{a}	7.5 ± 0.9^{a}
320 W, 32 min	18.05 ± 0.27^{b}	1.01 ± 0.37^{c}	21.44 ± 0.54^{b}	5.5 ± 0.8^{b}

[a-d] Mean within the column values with different letters are significantly different (P ≤0.05)

Table 2. Proximate composition of cooked brown rice at 300W for 48 min

Assay	Before microwave drying (g/100 g dry matter)*	After microwave drying (g/100 g dry matter)*
Protein	12.95 ± 0.19^{a}	12.70 ± 0.11^{a}
Crude fat	2.19 ± 0.04^{a}	1.64 ± 0.03^{b}
Ash	1.61 ± 0.02^{a}	1.42 ± 0.05^{a}
Fiber	1.06 ± 0.03^{a}	1.04 ± 0.02^{a}
Carbohydrate	82.19 ± 0.19^{a}	83.20 ± 0.13^{a}

* Data represent the mean of three replicates ± standard deviation

[a, b] Values in the same row with different superscripts are significantly different (P ≤ 0.05)

Table 3. Mineral composition of cooked brown rice at 300W for 48 min

Mineral	Before microwave drying (mg/100 g)*	After microwave drying (mg/100 g)*	DRI (mg/a day)
Potassium (K)	340.55 ± 16.55^{a}	279.94 ± 29.61^{a}	4700
Magnesium (Mg)	155.22 ± 7.11^{a}	161.28 ± 12.19^{a}	310-420
Zinc (Zn)	2.51 ± 0.09^{a}	2.88 ± 0.88^{a}	8-11
Manganese (Mn)	4.42 ± 0.20^{a}	2.45 ± 0.15^{b}	1.8-2.3
Copper (Cu)	0.23 ± 0.05^{a}	0.14 ± 0.04^{b}	900 µg

* Data represent the mean of three replicates ± standard deviation

[a, b] Values in the same row with different superscripts are significantly different (P ≤ 0.05)

brightness and redness than the fresh cooked brown rice. The darker appearance of the dried brown rice may be due to the pigment. Normally, whole grain pigmented rice contains high amounts of phenolic compounds, especially anthocyanins in the pericarp (Abdel-Aal *et al*., 2006). In 2008, Yang et al. reported that during the heating of aqueous anthocynains it was observed that the L* and a* values decreased through time, while b* values increased. Similar findings were also reported by Reyes and Cisneros-Zevallos, (2007).

The results of the sensory color attributes of the cooked and dried brown rice are also summarized in Table 1. The data were subjected to the ANOVA test. It appeared that use of microwave drying did not adversely affect the color of dried brown rice too much. Consumer panels preferred the color of dried brown rice at 300 W for 48 min (hedonic value of 7.5, rated from "like moderately" to "like very much") than when treated with higher microwave power for a shorter time at 320 W for 32 minutes (hedonic value of 5.5, rated from "neither like nor dislike" to 'like slightly") or lower power for a longer time at 280 W for 70 min (hedonic value of 6.8, rated "like moderately"). Therefore, the nutritional value and trace elements of dried brown rice at 300 W for 48 min were chosen to be analyzed.

Proximate analysis of cooked brown rice

The proximate composition of cooked brown rice both before and after microwave drying at 300 W for 48 min is listed in Table 2. Changes in chemical composition (crude protein, total ash, crude fiber and carbohydrate) were found to be not significant (P>0.05) for cooked brown rice both before and after drying. The decrease of fat content was found to be significant (P≤0.05) after drying. This might be related to the rate of the food temperature change because it dried quicker and the fact that the concentrated lipids were removed during the drying. Normally, free lipids in cereal grains are adsorbed to the surface of starch granules (Kitahara *et al*., 1994) where they could take off lipids. In addition, the microwave energy increased the temperature of the rice and led to water evaporation. Therefore, the content of free fatty acid was reduced. These changes were similar to Zhao *et al*., (2007).

The protein content of cooked brown rice both before and after drying was approximately 11 %. From this result, note that microwave drying did not affect the protein composition. Others have reported that the crude protein content of brown rice ranged from 6% (Heinemann *et al*., 2005) to 9% (Moongngarm and Saetung, 2010). These differences are probably due to the types of brown rice. However, the cooked brown rice produced by Sangyod Muang Phatthalung can be a good source of functional protein for various uses in a food system.

Mineral composition of cooked brown rice

The mineral composition of cooked brown rice both before and after microwave drying at 300 W for 48 min is in Table 3. It seems that K, Mg and Zn before microwave drying did not differ significantly (P>0.05) after it. Mn and Cu before drying were slightly different from after drying (P≤0.05). From these results, K was the most abundant mineral in cooked brown rice followed by Mg, Ca, Zn, Mn and Cu. The K and Mg contents of cooked brown rice were found from 279.94 to 340.55 mg/100g and 155.22 to 161.28 mg/100 g respectively. The values of K and Mg were higher than the values usually present (Heinemann et al., 2005; Ogiyama et al., 2008). Furthermore, the values of average intake of the essential elements were compared with the daily dietary reference intake (DRI) of adult females and males aged between 19 - 50 years set by the Institute of Medicine (IOM), 2004. The results show that cooked brown rice made by Sangyod Muang Phatthalung is a good source of K, Mg, and Mn.

Conclusions

The experiments on the effect of using a power controlled microwave oven on cooked brown rice gave the following results. Consumer panels gave a high color acceptance score for the drying done at 300 W for 48 min. Most nutritional value of cooked brown rice could not be damaged by microwave drying. No statistical differences in changes of trace minerals potassium (K), magnesium (Mg), and zinc (Zn) both before and after drying were observed. The results indicated that microwave drying can be used for the drying of cooked brown rice.

Acknowledgements

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