QUALITY AND DRYING KINETICS OF INSTANT PARBOILED RICE FORTIFIED WITH TURMERIC USING HOT AIR AND MICROWAVE-ASSISTED HOT AIR DRYING

1. Introduction

Rice is consumed in different forms such as white rice, brown rice and processed rice. The parboiled rice, coated rice, instant rice and germinated brown rice are an example of the processed rice. The consumption of rice depends on the region, culture and eating style of the consumers. Instant rice concept has been of growing interest for the consumers who have adapted accelerated pace of modern life (Prasert et al., 2009; Jiaoa et al., 2013; Boluda-Aguilar et al., 2013; Huang et al., 2014). This is because instant rice takes a short cooking time. Instant rice can be prepared from many raw rice such as white rice, brown rice and parboiled rice. The white rice is normally used to prepare instant rice since it provides the soft texture after rehydration. To prepare the instant rice, the raw rice is cooked to gelatinize its starch and dried to the desired final moisture content. During preparation of instant rice, it leads to losses of some minerals, vitamins and phytochemicals. The fortification of cooked raw rice with natural additives before drying helps to improve its functionality. Natural antioxidants are one of the food additives that are used to improve nutritional and functionality of foods. Phenolic compounds are the natural antioxidants that are used to add in many foods because they have many benefits to consumers such as antioxidants, anti-aging, anti-viral, prevention of cardiovascular diseases and some cancers (Larson, 1988; Gerber et al., 2002; Kim et al., 2003).

The turmeric rhizomes (*Curcuma longa* L.) are one of the herbs that are widely used as food ingredients, food additives (Jayaprakasha et al., 2005; Surojanametakul et al., 2010) and colouring agent in foods (Sowbhagya et al., 2005). Curcuminoids, namely, curcumin, demethoxycurcumin and bisdemethoxycurcumin are major active components of turmeric rhizomes. The curcuminoids are found to be a rich source of phenolic compounds which have high antioxidant capacity and also stable to heat (Paramera et al., 2011). Curcuminoids are beneficial to health of consumers since they act as antioxidant, anti-inflammatory, antitumor, antiviral, anticancer and antimutagen (Polasa et al., 1991; Selvam et al., 1995). Thus, the application of turmeric rhizomes in food processing is of interest.

To prepare the instant rice, drying is an important process. The cooked raw rice needs to be dried to a certain moisture content for safe storage and easy handling. For drying, there are many drying techniques that can be applied to dry the cooked raw rice, for example sun drying, hot air drying, infrared drying, fluidized bed drying, microwave drying and microwave-assisted hot air drying. In the drying process, the drying method not only affects the drying time but also influences the product quality and energy efficiency. Hot air (HA) drying is the conventional method that has been used for a long time in many food industries. This is because drying with hot air is simple and easy. However, drying with hot air takes a long drying time, which influences the product quality and energy efficiency (Khraisheha et al., 2004; Cui et al., 2003). Thus, the implementation of new drying technique such as microwave-assisted hot air (MWHA) drying is more interesting in many food industries. This is because drying with MWHA not only improves the energy efficiency but also helps to maintain the product quality (Andrés et al., 2004; Zhang et al., 2010; Śledź et al., 2013). The objective of this work was therefore to study the effect of drying methods including HA and MWHA on the quality and drying kinetics of instant parboiled rice fortified turmeric (IPRFT). The quality of dried IPRFT was evaluated in terms of color, volume expansion, rehydration ratio, texture, total antioxidant capacity (TAC) and total phenolics content (TPC) and the drying kinetics during drying cooked parboiled rice fortified with turmeric was investigated.

2. Materials and Methods

2.1 Raw materials

The long grain parboiled rice and the turmeric powder (SURAJ brand, USA) that used in this study were purchased from Provigo supermarket, Montreal, Canada.

2.2 Cooking procedure

In this study, the long grain parboiled rice (LGPR) was cooked with turmeric powder in exact water by steaming method (Okabe, 1979). For each batch of cooking, 70 g LGPR was placed in the stainless steel tea strainer and washed with distilled water for 30 s in order to clean and remove the dust. After washing, the free water was removed by straining through a tea strainer and the remainder was absorbed by napkin paper. The washed LGPR was transferred to the aluminium pan with the size of 13 cm x 10.5 cm x 4.6 cm. 140 g distilled water (parboiled rice and water ratio of 1:2) was then added and mixed thoroughly. 0.7 g turmeric powder was then added into the aluminium pan and mixed thoroughly. The aluminium pan without the lid was steamed by electric rice cooker (Black & Decker; Rice Cooker Plus^{TM}, Model RC866C, China) for 30 min. After steaming, the rice cooker was turn-off and the cooked sample was allowed to stay in the rice cooker for 15 min. The cooked sample was removed from the rice cooker and it was then kept in the plastic zip bag and allowed cooling to ambient temperature for 90 min.

2.3 Experimental setup

Drying of cooked long grain parboiled rice fortified with turmeric was performed using the automated microwave assisted thermal processor (AMATP) as shown in Figure 1. The main components of AMATP were: a 2450 MHz microwave generator (Gold Star 2M214, South Korea) that can be adjusted to the microwave power ranging from 0 to 750 W, waveguides with the dimension of 7.2 cm x 3.5 cm, a three-port circulator (Apollo, model 12946, Canada), a manual three stub tuner, microwave measured probes and meters, carbon load and microwave cavity. The generated microwaves from microwave generator were guided into the microwave cavity via the above mentioned components in a sequence (Dev et al., 2008) . The manual three stub tuner was used to adjust the reflected microwaves by controlling it at a minimum possible value (<10% of the incident power). The carbon load that was connected with three-port circulator was used to absorb the reflected microwaves. The microwave cavity was made of brass and rectangular shape with the dimension of 47 cm x 47 cm x 27 cm. During the drying process the product temperature was measured using fibre optic probe (Nortech Fibronic INC, model Canada).The probe was connected to a data acquisition unit (Agilent, model 34970A, USA) which was connected to a computer. The adjustable speed axial fan was used to supply the air to the microwave cavity. For this work, the volume of inlet air was fixed at 0.21 m^3/s. Before flowing though the microwave cavity, the air was heated by two electrical heaters, each rate at 1200 W and the temperature of heated air was controlled by proportional-integral-differential (PID) controller with an accuracy of ±1 °C (Omega, model CN132, Canada). The heated air entered the microwave cavity through the air distributor plate, which had a hole size of 3 mm. The AMATP was also equipped with an electronic balance (Imperial Instrument, model TM-2, Switzerland) which was used to record the mass of the sample during drying. The entire setup was continuously monitored and controlled via the computer that was connected with HP VEE (Agilent) object-oriented programming language (Dev et al., 2008).

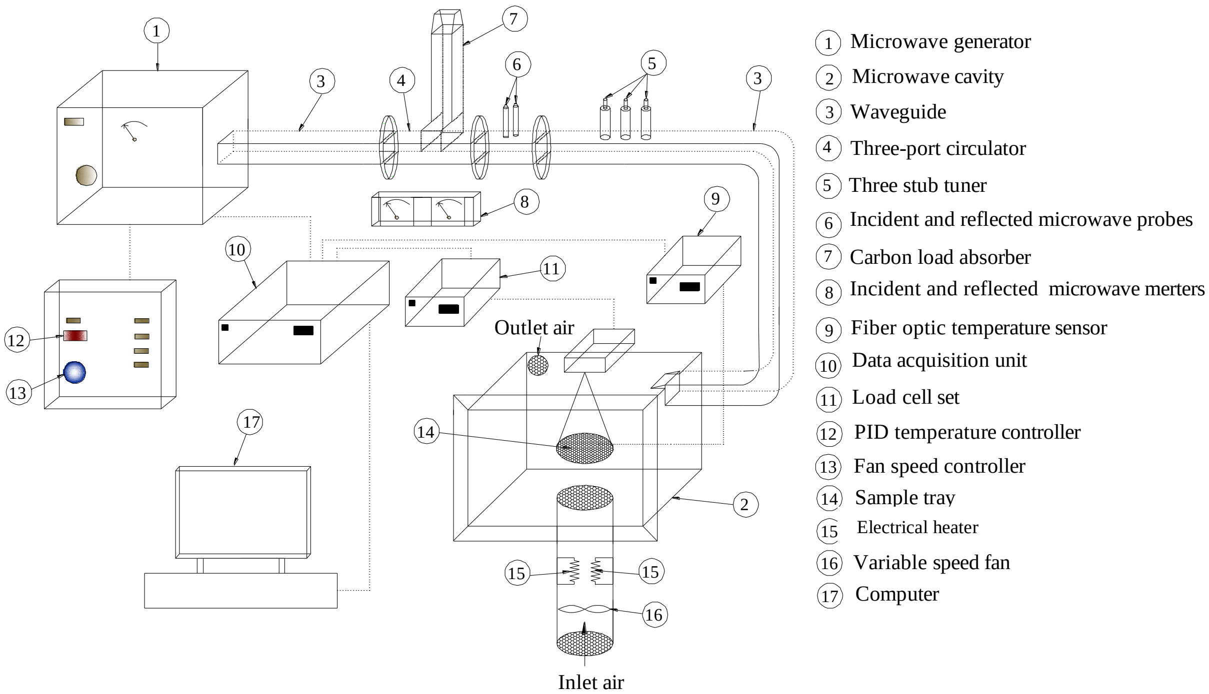

Figure 1 Schematic diagram of automated microwave assisted dryer

(Modified from Dev et al., 2008)

2.4 Drying procedure

For each batch of drying, 170 g of cooked LGPR fortified with turmeric was dried by AMATP using the HA and MWHA as the drying medium. The cooked sample was dried in the tray which was made from nylon mesh and it had the diameter of 20.5 cm.

The thickness of the sample in the tray was 1.0 cm. The sample tray was then transferred to the microwave cavity. For drying with HA, the experiment was performed at the air temperature of 65, 80, 95 and 110 °C. In the case of drying with MWHA, the microwave power at the density of 0.588 W/g was incorporated at each air temperature. The set point microwave power, the maximum incident power and the maximum reflected power were kept at 100, 200 and 100 W, respectively, for all the experiments. The volumetric flow rate of inlet air was fixed at 0.21 m^3/s which was measured by the turbine anemometer (Kestrel-1000, USA) (Nair et al., 2012). The drying was performed until the sample reached a final moisture content of 16 % (dry basis). After drying process, the dried sample was transferred into the plastic zip bag and kept in the refrigerator at 5 °C until the quality was evaluated.

2.5 Drying Kinetics

The change of moisture content of cooked long grain parboiled rice fortified with turmeric powder during drying at each drying condition was presented in terms of moisture ratio (*MR*) as shown in equation (1).

$$MR = \frac{M_{\mathrm{t}} - M_{\mathrm{e}}}{M_{\mathrm{i}} - M_{\mathrm{e}}} \tag{1}$$

The M_{t} is the moisture content at each drying time (% d.b.), M_{e} is the equilibrium moisture content (% d.b.) and M_{i} is the initial moisture content (% d.b.). In this work, the equilibrium moisture content was assumed as zero. This is because the equilibrium moisture content is very low as compared to initial moisture content of cooked sample (Doymaz and Pala, 2003; McMinn, 2006; Sacilik, 2007).

2.6 Moisture content determination

The moisture content of samples were determined by drying method using the hot air oven (Precision, Thermo Electron Model, USA) at 105 °C for 72 hours and then the moisture content of the sample can be calculated.

2.7 Color measurement

The color of sample was measured by the chroma meter (Minolta model: CR-300, Japan). Before measuring the color, the chroma meter was calibrated with a standard white plate (Y = 93.35, x = 0.3152, y = 0.3212). The D65 was used as light source and the CIE1976 ($L^*a^*b^*$) color scale was used as color descriptor. The L^*, a^* and $b^*$are represented of the lightness-blackness, redness-greenness and yellowness-blueness. The color value of each experimental replicate was measured in triplicates and the average value of each condition was presented.

2.8 Rehydration ratio determination

The rehydration ratio of dried IPRFT was determined by boiling method. Five grams of dried IPRFT was placed in the stainless steel tea strainer and then it was dipped in boiling water at the temperature of 99±1 °C. The sample was weighted every 2 min for 14 min. The rehydration ratio of rehydrated IPRFT can be calculated by equation (2).

$$\text{Rehydration ratio} = \frac{W_\mathrm{t} - W_\mathrm{i}}{W_\mathrm{i}} \tag{2}$$

Where W_t is the weight of rehydrated IPRFT at every 2 min (g) and W_i is the initial weight of IPRFT (g) before rehydration.

2.9 Volume expansion ratio determination

The volume expansion ratio of rehydrated IPRFT is determined by the volume replacement method (Boluda-Aguilar, 2013). Before rehydration, 5 g of dried IPRFT was poured into 50 mL cylinder and then 20 mL of distilled water was added. After adding the distilled water, the volume of the mixture was recorded rapidly. Then, the mixture was poured into the tea strainer to remove the distilled water. The wet IPRFT was then rehydrated in the boiling water at a temperature of 99±1 °C for 12 min. After rehydration, the rehydrated IPRFT was poured into 50 mL cylinder and 20 mL of distilled water was added. An increase in the volume after adding the distilled water was recorded rapidly. The determination was performed in triplicate of each experimental replicate. The volume expansion of rehydrated IPRFT can be calculated by equation (3).

$$\text{Volume expansion} = \frac{V_\mathrm{r} - V_\mathrm{i}}{V_\mathrm{i}} \tag{3}$$

Where V_r is the volume of rehydrated IPRFT (mL) and V_i is the volume of IPRFT before rehydration (mL).

2.10 Textural property

The textural property of rehydrated IPRFT was presented in term of hardness. It was measured by the Instron texture analyzer (Model 4502, England) with 19.6 N load cell. Before testing, the dried IPRFT was rehydrated in exact water at ratio of 2:1 (water to dried IPRFT) for 12 min. For testing, 6 kernels of rehydrated IPRFT were placed onto the stainless steel rectangular plate. The PE cylindrical probe with a diameter of 25 mm was used to compress the sample to 70% deformation at a speed of 2 mm/min. After compression, the value of hardness was reported. The measurement was performed in six replicates and the average value was reported.

2.11 Sample extraction to evaluate TPC and TAC

Two grams of ground sample was mixed with 25 mL of methanol (99.9% v/v) (Fisher Chemical, Trinidad) in 50 mL mixing tube and then it was shaken at 175 rpm at the temperature of 30 °C for 24 hours. The mixture was then filtered through a Whatman No. 4 filter paper. The filtered solution was adjusted to the volume of 25 mL with methanol in the volumetric flash. The extract solution was kept in the refrigerator at the temperature of 5 °C before analysis. The extraction was carried out in two replicates of each experimental replicate.

2.12 Total phenolic content (TPC) determination

Total phenolic content of extract solution was determined using Folin-Ciocalteu reagent with modified method of Singleton and Rossi (1965). An amount of 320 µL of extract solution was mixed with 1600 µL of Folin-Ciocalteu reagent, which was previously diluted ten-fold with the deionized water. After that, 800 µL of 7.5% (w/v) of sodium carbonate (Na_2CO_3) solution was added and the mixture was vortexed for 10 s. After 3 min, 1600 µL of deionized water was then added into the mixture and it was vortexed for 10 s. The mixture was heated in a water bath at 40 °C for 30 min. The absorbance of mixture was measured using a UV-VIS scanning spectrophotometer (Biochrom, Ultrospec 2100 pro, England) at a wavelength of 765 nm. The TPC of sample was determined against the standard curve of Gallic acid and the result was expressed as mg Gallic acid equivalent (GAE) per 100 g of dry sample. The measurement was carried out in triplicates of each experiment and the average value was determined.

2.13 Total antioxidant capacity (TAC) determination

The total antioxidant capacity (TAC) of samples was evaluated based on the free radical scavenging effect of 2, 2-diphenyl-1-picryl-hydrazyl (DPPH) (Sigma-Aldrich Inc, USA). The DPPH scavenging activity of extract sample was determined using a modified method of Onichi et al. (1994). A 270 µL of extract sample was mixed with 1620 µL of 0.10 mM DPPH that was prepared in methanol. The mixture was vortexed for 10 s and let it to stand at room temperature under dark for 20 min. Then, the mixture absorbance at the wavelength of 517 nm by a UV visible spectrophotometer (Biochrom, Ultrospec 2100 pro, England) was measured. The percentage of DPPH scavenging activity (SCA) was calculated by the equation SCA (%) = $((Ab_{blank}-Ab_{sample})/Ab_{blank})\times 100$, where Ab_{blank} is the absorbance of blank (0.1 mM of DPPH solution) and Ab_{sample} is the absorbance of sample. A standard curve of free radical scavenging activity of t-butylated hydroxyanisole (BHA) at each concentration was prepared. The TAC of extract sample was analyzed against the standard curve of BHA and the results were expressed as mg BHA equivalent (BHAE) per 100 g of dry sample. The measurement was carried out in triplicate for each experiment and the average value was determined.

2.14 Statistical analysis

All data were analysed to indicate the significant difference of quality among treatments by the analysis of variance (One-way ANOVA) using SPSS software. Differences between mean values were established using Tukey's HSD tests at a confidence level of 95% ($p<0.05$). The results were presented as mean values ± standard deviations (SD).

3. RESULTS AND DISCUSSION

3.1 Drying characteristics

The drying characteristic curve of cooked long grain parboiled rice fortified with turmeric during drying with HA and MWHA is shown in Figure 2 and Figure 3. As can be seen in Figure 2, drying of cooked sample to desired final moisture content with MWHA was faster than drying with HA. For drying with HA at the temperatures of 65, 80, 95 and 110 °C the drying times were 160, 130, 102 and 97 min, respectively. As expected, the drying time of HA drying decreased by increasing the drying temperature. This is because an increase in drying temperature provided a higher drying rate as depicted in Figure 3. However, it is observed that an increase in drying temperature from 95 °C to 110 °C had the less effect on drying time. When the microwaves at the microwave power density of 0.588 W/g was incorporated with hot air at each temperature, the drying time was 80, 60, 53 and 50 min for drying temperature of 65, 80, 95 and 110 °C, respectively. These results clearly showed that incorporation of microwaves at a given microwave power density helped to reduce the drying time around 50% as compared to drying with hot air. This is due to the fact that an incorporation of microwave with hot air for drying helps to improve the moisture diffusion rate. As can be seen in Figure 4, the product temperature of MWHA drying rapidly increased at the early period of drying due to the absorption of microwave power by water molecules, resulting in the volumetric heating generation within the material. Consequently, the moisture from inner layer of material can move rapidly to the surface.

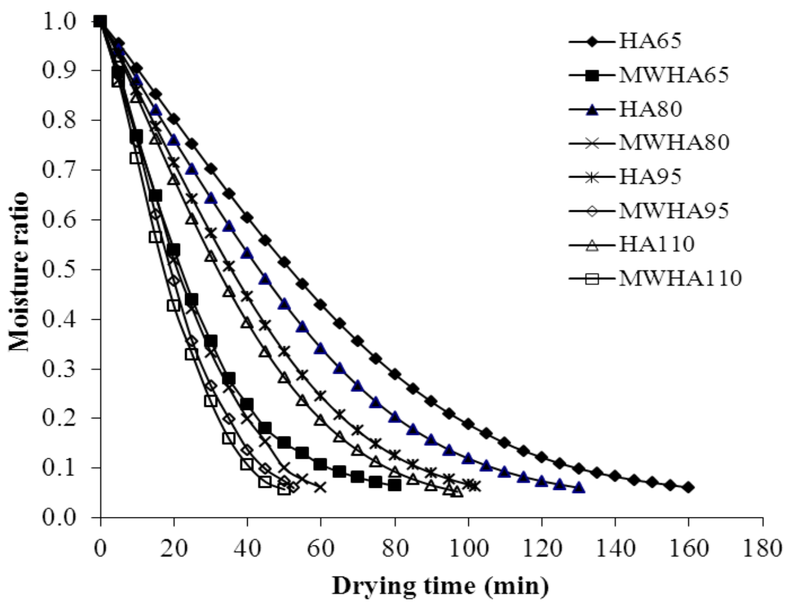

Figure 2 Drying curves during drying with hot air (HA) at temperatures of 65, 80, 95 and 110 °C and microwave-assisted hot air (MWHA) at microwave power density of 0.588 W/g and air temperatures of 65, 80, 95 and 110 °C

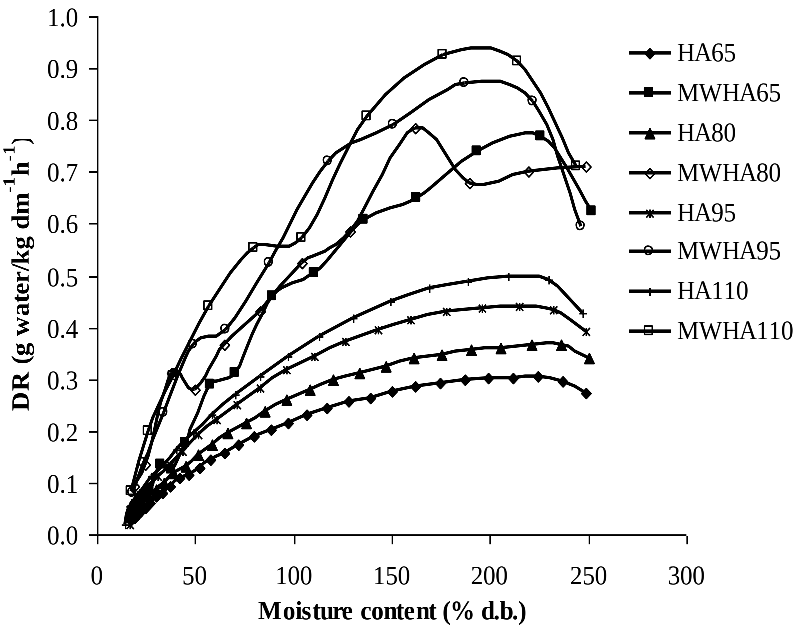

Figure 3 Drying rate (DR) of cooked samples at each condition

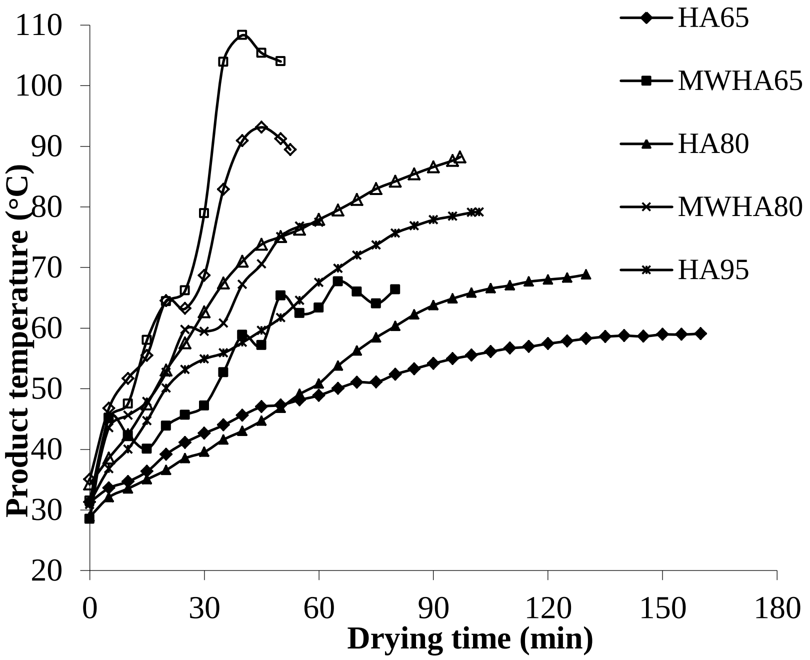

Figure 4 Product temperature during drying at each condition

3.2 Color

Table 1 shows the color of dried IPRFT at different drying conditions. It was found that the color of dried IPRFT was in the reddish-yellow range which corresponded to the lightness (L^*) of 48.16-56.44, redness (a^*) of 3.33-4.66 and yellowness (b^*) of 53.26-58.38. As can be seen in Table 1, drying with hot air (HA) and microwave-assisted hot air (MWHA) at a given conditions insignificantly affected the lightness of dried IPRFT. However, it is observed that the lightness of dried products tended to increase with increase in drying air temperature from 65 °C to 80 and 95 °C both in the cases of HA and MWHA drying. This is due to the fact that the drying time was shorter at a higher drying air temperature. But, when the drying temperature was increased from 95 °C to 110 °C for both HA and MWHA drying, the lightness of dried product tended to decrease. This may be due to the effect of thermal browning reaction which can be observed from the highest redness value of dried product. Considering the effect of drying temperature and drying methods on the redness and yellowness of dried IPRFT, the results showed that drying with HA and MWHA did not affect the redness and yellowness of dried IPRFT. Except, when the drying temperature was increased from 95 °C to 110 °C, the trend of redness and yellowness of dried IPRFT changed.

Table 1 color of cooked parboiled rice fortified turmeric after drying at different conditions

Drying condition	Color values		
	L^*	a^*	b^*
HA65	48.16 ± 2.87^{a}	3.49 ± 0.90^{a}	53.26 ± 2.71^{a}
HA80	$51.11 \pm 1.54^{a,b}$	3.86 ± 0.72^{a}	$57.29 \pm 2.05^{a,b}$
HA95	52.42 ± 2.66^{b}	3.86 ± 0.79^{a}	58.38 ± 3.21^{a}
HA110	$49.88 \pm 1.67^{a,b}$	4.09 ± 0.82^{a}	$54.48 \pm 1.18^{a,b}$
MWHA65	$50.31 \pm 3.39^{a,b}$	3.72 ± 1.09^{a}	$55.62 \pm 3.24^{a,b}$
MWHA80	$51.00 \pm 2.65^{a,b}$	3.33 ± 1.03^{a}	$55.69 \pm 3.84^{a,b}$
MWHA95	$56.44 \pm 2.59^{a,b}$	3.98 ± 1.15^{a}	$56.36 \pm 2.83^{a,b}$
MWHA110	$49.71 \pm 1.89^{a,b}$	4.66 ± 0.82^{a}	$54.72 \pm 2.50^{a,b}$

Different superscripts in the same column mean that the mean values are significantly different at $p<0.05$

3.3 Volume expansion

The volume expansion of dried IPRFT after rehydration in boiling water for 12 min is presented in Figure 5. It was found that the volume expansion ratio of rehydrated IPRFT was in the range of 2.95-3.01. These results revealed that drying with HA or MWHA under studied conditions did not affect the volume expansion ratio of rehydrated IPRFT as indicated by the statistical analysis, which is similar to the results of Prasert and

Suwannaporn (2009). They found that drying temperature did not affect the volume expansion of rehydrated instant jasmine rice. For preparation of instant rice, Smith et al. (1985) suggested that the volume expansion of rehydrated instant rice should be increased as 1.5-3 times after rehydration.

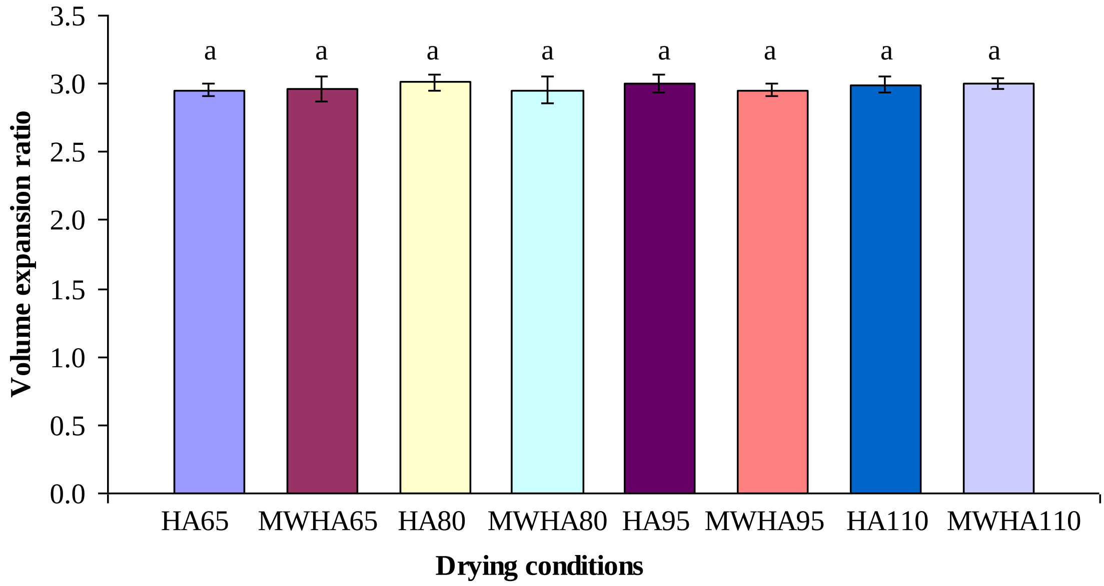

Figure 5 Volume expansion ratio of rehydrated IPRFT

3.4 Rehydration ratio

The rehydration curves of dried IPRFT are presented in Figure 6. It is seen that the rehydration ratio was increased with increase in the rehydration time. At the rehydration time for 14 min, the rehydration ratio of rehydrated IPRFT was in the range of 2.04-2.12. Considering the effect of drying methods and drying temperature on the rehydration ratio, it was found that drying with HA or MWHA at higher drying temperature did not influence the rehydration ratio of rehydrated IPRFT. This result was similar to the work of Luangmalawat et al. (2008) and Prasert and Suwannaporn (2009).

They found that the drying temperature did not affect the rehydration ratio of the rehydrated instant white rice.

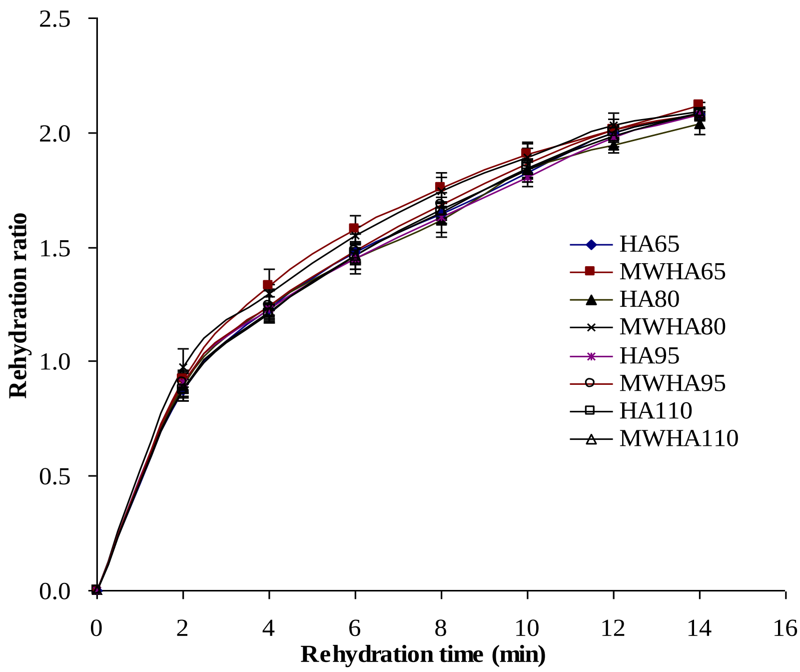

Figure 6 Rehydration ratio of dried IPRFT at each rehydration time

3.5 Hardness of rehydrated IPRFT

Table 2 shows the hardness of dried IPRFT after rehydration in exact water for 12 min. It was found that the hardness of rehydrated IPRFT was in the range of 31-33 N. Drying with HA and MWHA at different temperatures did not influence the hardness of rehydrated IPRFT. The hardness of rehydrated IPRFT corresponded to the volume expansion ratio and rehydration ratio which was not significantly different after rehydration for 12 min.

Table 2 Hardness and breaking energy of rehydrated IPRFT

Drying conditions	Hardness (N)
HA65	32.43±3.52[a]
HA80	33.08±3.59[a]
HA95	32.67±2.81[a]
HA110	32.32±2.71[a]
MWHA65	31.27±2.43[a]
MWHA80	31.67±3.34[a]
MWHA95	31.03±2.51[a]
MWHA110	33.16±4.83[a]

Different superscripts in the same column mean that the mean values are significantly different at $p<0.05$

3.6 phenolic content and total antioxidant capacity of dried IPRFT

Table 3 shows the total phenolic content (TPC) and total antioxidant capacity (TAC) of IPRFT after drying at different conditions. Before processing, the long grain parboiled rice had an initial TPC of 9.74 mg GAE/100 g of dried sample and had initial TAC of 5.19 mg BHAE/100 g dried sample. After cooking long grain parboiled rice with turmeric powder and dried at various conditions, the experimental results showed that the TPC and TAC of dried IPRFT was given in the range of 16.62-17.89 mg GAE/100 g of dried sample and 9.21-10.05 mg BHAE/100 g dried sample, respectively. Both TPC and TAC of dried IPRFT were clearly increased as compared to the TPC and TAC of initial long grain parboiled rice. Considering the effect of drying conditions on the TPC and TAC of dried IPRFT, it was found that drying among conditions insignificantly affected both TPC and TAC of dried IPRFT.

Table 3 Total antioxidant capacity (TAC) and total phenolic content (TPC) of dried IPRFT

Drying conditions	TPC (mg GAE/100 g dried sample)	TAC (mg BHAE/100 g dried sample)
HA65	17.33±1.09[a]	9.72±1.00[a]
HA80	17.36±1.45[a]	9.93±1.01[a]
HA95	17.89±0.60[a]	9.80±0.89[a]
HA110	16.62±0.86[a]	9.64±1.16[a]
MWHA65	16.70±1.11[a]	9.21±1.16[a]
MWHA80	17.79±0.83[a]	10.06±1.27[a]
MWHA95	16.84±1.13[a]	9.53±1.12[a]
MWHA110	17.11±0.93[a]	10.00±0.53[a]

Different superscripts in the same column mean that the mean values are significantly different at $p<0.05$

4. Conclusion

The quality and drying kinetics of instant parboiled rice fortified with turmeric (IPRFT) that was dried with hot air (HA) and microwave-assisted hot air (MWHA) at different temperatures were investigated. The experimental results indicated that drying of cooked sample by incorporation of microwaves with hot air at each temperature helped to improve the drying time by about 50%. Drying conditions had small effect on the color of dried IPRFT. The volume expansion ratio, rehydration ratio and hardness of rehydrated IPRFT were not significantly different among the drying conditions. Total phenolics content (TPC) and total antioxidant capacity (TAC) of dried IPRFT clearly increased as compared to the TPC and TAC of initial long grain parboiled rice and the drying conditions did not affect the TAC and TPC of dried IPRFT.

5. References

Andrés, A., Bilbao, C. and Fito, P., 2004, “Drying kinetics of apple cylinders under combined hot air–microwave dehydration”, **Journal of Food Engineering**, Vol. 63, pp. 71-78.

Boluda-Aguilar, M., Taboada-Rodríguez, A., López-Gómez, A., Marín-Iniesta, F. and Barbosa-Cánovas. G.V., 2013, “Quick cooking rice by high hydrostatic pressure processing”, **LWT - Food Science and Technology**, Vol. 51, pp. 196-204.

Cui, Z.-W., Xu, S.-Y. and Sun, D.-W., 2003, “Dehydration of garlic slices by combined microwave-vacuum and air drying”, **Drying Technology: An International Journal**, Vol. 21, pp. 1173-1184.

Dev, S.R.S., Raghavan, G.S.V. and Gariepy, Y., 2008, “Dielectric properties of egg components and microwave heating for in-shell pasteurization of eggs”, **Journal of Food Engineering**, Vol. 86, pp. 207–214.

Doymaz, I. and Pala, M., 2003, “The thin-layer drying characteristics of corn”, **Journal of Food Engineering**, Vol. 60, pp. 125-130.

Gerber, M., Boutron-Ruault, M.-C., Hercberg, S., Riboli, E., Scalbert, A. and Siess, M.-H., 2002, “Food and cancer: state of the art about the protective effect of fruits and vegetables”, **Bulletin du Cancer**, Vol. 89, pp. 293-312.

Huang, M., He, G., Chen, S., Cui, M., Ma, L. and Liu, Y., 2014, "Optimisation of a quality improver for instant rice and its quality properties", **International Journal of Food Science and Technology**, Vol. 49, pp. 606-615.

Jayaprakasha, G.K., Rao, L.J. and Sakariah, K.K., 2005, "Chemistry and biological activities of C. longa", **Trends in Food Science & Technology**, Vol. 16, pp. 533-548.

Jiaoa, A., Xua, X. and Jin, Z., 2013, "Modelling of dehydration–rehydration of instant rice incombined microwave-hot air drying", **Food and Bioproducts Processing**, Vol. 92, pp. 259-265.

Khraisheha, M.A.M., McMinnb, W.A.M. and Mageeb T.R.A., 2004, "Quality and structural changes in starchy foods during microwave and convective drying", **Food Research International**, Vol. 37, pp. 497-503.

Kim, D.-O., Jeong, S.W. and Lee, C.Y., 2003, "Antioxidant capacity of phenolic phytochemicals from various cultivars of plums", **Food Chemistry**, Vol. 81, pp. 321-326.

Larson, R.A., 1988, "The antioxidants of higher plants", **Phytochemistry**, Vol. 27, pp. 969-978.

Luangmalawat, P., Prachayawarakorn, S., Nathakaranakul, A. and Soponronnarit, S., 2008, "Effect of temperature on drying characteristics and quality of cooked rice", **LWT-Food Science and Technology**, Vol. 41, pp. 716-723.

McMinn, W.A.M., 2006, “Thin-layer modeling of the convective, microwave, microwave-convective and microwave-vacuum drying of lactose powder”, **Journal of Food Engineering**, Vol. 72, pp. 113-123.

Nair, G.R., Liplap, P., Gariepy, Y. and Raghavan, G.S.V., 2012, “Effect of microwave and hot air drying on flax straw at controlled temperatures”, **International Journal of Postharvest Technology and Innovation**, Vol. 2, pp. 355-369.

Okabe, M., 1979, “Texture measurement of cooked rice and its relationship to the eating quality”, **Journal of Texture Studies**, Vol. 10, pp. 131-152.

Onichi, M., Morishita, H., Iwahashi, H., Toda, S., Shirataki, Y., Kimura, M. and Kido, R., 1994, “Inhibitory effects of chlorogenic acids on linoleic acid peroxidation and hemolysis”, **Phytochemistry**, Vol. 36, pp. 579-583.

Paramera, E.I., Konteles, S.J. and Karathanos, V.T., 2011, “Stability of release properties of curcumin encapsulated in Saccharomyces cerevisae, β-cyclodextrin and modified starch”, **Food Chemistry**, Vol. 125, pp. 913-922.

Prasert, W. and Suwannaporn, P., 2009, “Optimization of instant jasmine rice process and its physicochemical properties”, **Journal of Food Engineering**, Vol. 95, pp. 54-61.

Polasa, K., Sesikaran, B., Krishna, T.P. and Krishnaswamy, K., 1991, “Turmeric (*Curcuma longa* L.) induced reduction in urinary mutagens”, **Food Chemistry and Toxicology**, Vol. 29, pp. 699-706.

Sacilik, K., 2007, “Effect of drying methods on thin-layer drying characteristics of hull-less seed pumpkin (*Cucurbita pepo* L.)”, **Journal of Food Engineering**, Vol. 79, pp. 23-30.

Selvam, R., Subramanian, L., Gayathri, R. and Angayarkanni, N., 1995, “The anti-oxidant activity of turmeric (*Curcuma longa*)”, **Journal of Ethnopharmacology**, Vol. 47, pp. 59-67.

Singleton, V. L. and Rossi, J.A., 1965, “Colorimetry of total phenolics with phosphomolibdic phosphotungstic acid reagent”, **American Journal of Enology Viticulture**, Vol. 16, pp. 144-158.

Śledź, M., Nowacka, M., Wiktor, A., and Witrowa-Rajchert, D., 2013, “Selected chemical and physico-chemical properties of microwave-convective dried herbs”, **Food and Bioproducts Processing**, Vol. 91, pp. 421-428.

Smith, D.A., Rao, R.M., Liuzzo, J.A. and Champagne, E., 1985, “Chemical Treatment and process modification for producing improved quick-cooking rice”, **Journal of Food Science**, Vol. 50, pp. 926-931.

Sowbhagya, H.B., Smitha, S., Sampathu, S.R., Krishnamurthy, N. and Bhattacharya, S., 2005, “Stability of water-soluble turmeric colourant in an extruded food product during storage”, **Journal of Food Engineering**, Vol. 67, pp. 367–371.

Surojanametakul, V., Satmalee, P., Saengprakai, J., Siliwan, D. and Wattanasiritham, L., 2010, "Preparation of curcuminoid powder from turmeric root (*Curcuma longa* Linn) for food ingredient use", **Kasetsart Journal (Natural Science)**, Vol. 44, pp. 123–130.

Zhang, M. Jiang, H. and Lim, R.-X., 2010, "Recent developments in microwave-assisted drying of vegetables, fruits, and aquatic product-drying kinetics and quality consideration", **Drying Technology: An International Journal**, Vol. 28, pp. 1307-1316.