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Microwave drying kinetics and quality characteristics of aromatic *Pandanus amaryllifolius* leaves

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Abstract: The effect of microwave drying technique on drying kinetics of aromatic *Pandanus* leaves (*Pandanus amaryllifolius*) was investigated. By increasing the microwave output powers (180-900 W), the drying time decreased from 14 to 2 min. To determine the kinetic parameters, the drying data were fitted to various models based on the moisture ratios versus drying time. Among the models proposed, the semi-empirical Page model gave the best fit for all drying conditions applied. The goodness of fit was determined using the coefficient of determination (R^2), reduced chi square (χ^2), root mean square error (RMSE). By increasing the microwave output powers, the effective moisture diffusivity values increased from 5.35E-08 to 1.99E-07 m^2/min. The activation energy was calculated using an exponential expression based on Arrhenius equation. Further, the effects of the drying conditions on the aromatic compound 2-acetyl-1-pyrroline of the *Pandanus* leaves were evaluated. Keeping in view the drying time, drying rate and sensory attributes of the leaves, it is proposed to dry the leaves at 540 W in a microwave dryer to obtain the product with good quality.

Keywords: Microwave drying, effective moisture diffusivity, activation energy, sensory evaluation

Introduction

Pandanus amaryllifolius belongs to the Pandanaceae family and is known for its aroma. *Pandanus amaryllifolius* Roxb. possess uniquely fragrant leaves and is widely cultivated in South East Asia, such as Thailand, Malaysia, Indonesia and India. The major constituent of these leaves i.e. 2-acetyl-1-pyrroline has commercial significance as a flavour constituent that imparts the characteristic aroma to scented rice varieties in India and in several Asian rice varieties (Buttery *et al*., 1982). *Pandanus* leaves are traditionally used for cooking common non-aromatic rice to impart a resemblance of the basmati aroma to the cooked rice. The compound can be added to non-aromatic rice varieties and rice-containing dishes. It can also be used to flavour meat and vegetable products or blended with other flavour enhancing sauces or compositions. Along with the aromatic properties the leaves have been reported to have compounds with antiviral (Ooi *et al*., 2004) and antioxidant (Nor *et al*., 2008) properties, which encourages the use of leaves. The leaves are perishable in nature because of high moisture content. For the effective utilization of the leaves, the postharvest processing aspect is important so that the quality of the leaves can be preserved with enhanced shelf life (Routray and Rayaguru, 2010). Dehydration is a useful method of preserving the leaves through which spoilage can be prevented (Maroulis and Saravacos, 2003). Standardization of drying parameters is vital for producing good quality leaves which can be further used for value addition and can be traded internationally. Thus controlled and appropriate drying of the leaves appears to be potential alternative measure for preserving the aromatic qualities of the leaves. Drying not only affects the water content of the product, but also alters other physical, biological and chemical properties such as aroma, and palatability of foods (Barbosa-Canovas and Vega-Mercado, 1996). In recent years, the drying behaviours of different aromatic plants and culinary herbs like parsley (Soysal *et al*., 2006), laurel (Yağcıoğlu *et al*., 1999), bay leaves (Günhan *et al*., 2005), dill (Raghavan *et al*., 1994), mint (Park *et al*., 2002; Lebert *et al*., 1992), and purslane (Kashaniinejad and Tabil, 2004) have been studied by many investigators. However, studies on the drying characteristics of *Pandanus* leaves are scarce in the literature.

Most of the conventional thermal treatments such as hot-air drying, vacuum drying, sun drying and freeze drying result in low drying rates in the falling rate period which leads to undesirable thermal degradation of the finished products (Mousa and Farid, 2002). In addition to its long time and environmentally dependent process, sun drying is not

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recommended from the hygienic point of view. They have also disadvantages like inconsistent quality standards, contamination problems, low energy efficiency and high costs which is not a desirable situation for the food industry (Soysal and Öztekin, 2001).

Microwaves are electromagnetic waves within the range of radio frequencies from 300 MHz to 300 GHz. Electromagnetic energy at 915 and 2450 MHz can be absorbed by water containing materials and is converted to heat (Maskan, 2000). Therefore, as compared to the above mentioned drying techniques; microwave drying offers opportunities as less drying time, uniform energy and high thermal conductivity to the inner sides of the material, space utilization, sanitation, energy saving, precise process control, fast start-up and shut down conditions with high quality finished products (Decareau, 1992; Zhang *et al*., 2006).

Therefore, the objectives of the present work were to: (a) determine the effects of power level of microwave drying on drying parameters and examine the feasibility of using microwave drying to dry *Pandanus amaryllifolius* efficiently to produce a high quality dried product, and (b) comparison of several drying equations to express the microwave drying kinetics of *Pandanus* leaves with the most suitable drying model.

Materials and Methods

Sample preparation

Fresh leaves of *Pandanus amaryllifolius* were plucked, washed free of dirt, wiped with a cloth and sliced into small portions of 10 cm long. Moisture content was measured by the gravimetric method using an electric convection oven and an electronic balance. Three 30 g leaf samples were dried in an oven at 105^0C for 24 h to determine initial moisture content. The initial moisture content of the *Pandanus* leaves was 4.41 kg of H_2O per kg dry matter. For the mass determination, a digital balance of 0.0001 g accuracy (ANAMED, M7000 series) was used. For calculation of the effective moisture diffusivity values of the *Pandanus* leaves, the thickness of the 50 samples was measured and the average thickness of leaves was found as 0.8 mm.

Quantification of 2-Acetyl-1-pyrroline

Likens–Nickerson concurrent steam-distillation-solvent extraction method was used to extract 2-acetyl-1-pyrroline from *Pandanus* leaves. The procedure was similar to that developed by Laksanalamai and Ilangantileke (1993). First, 4 l of distilled water and 4 ml of antifoaming agent (silicone oil) were placed in a 5 l round-bottom flask, and boiled to obtain a volatile-free mixture. The boiling was continued until the volume of the mixture was reduced by 500 ml. 250 g of fresh *Pandanus* leaves were blended and mixed with 800 ml distilled water, and then filtered to remove the blended leaf residues. The filtrate was made up to 1000 ml with distilled water and the resulting *Pandanus* solution was added gradually to the volatile-free mixture in the round-bottom flask. The mixture was steam-distilled and the flavour extract was collected in a 250 ml round-bottom flask containing 80 ml of distilled water, 2 ml of dilute sulphuric acid and 120 ml of diethyl ether; maintained at 50°C. After 2 hours of continuous steam-distillation and solvent extraction in diethyl ether, the solvent flask was removed and the sulphuric acid layer was transferred into a 250 ml Erlenmeyer flask, using a 250 ml separating funnel. The solution was neutralized by adding solid sodium bicarbonate, and then poured into a clean 250 ml separating funnel containing 120 ml of fresh diethyl ether. The separating funnel was shaken vigorously until the diethyl ether (upper layer) was clearly separated from the neutral solution (lower layer). The upper layer was poured into a clean 250 ml Erlenmeyer flask and the lower layer was discarded. Anhydrous sodium sulphate was added to the flask to remove dissolved water. Filtering through a non-absorbent cotton bed of anhydrous sodium sulphate further dried the ether extract. The dry ether extract was then filtered through a Whatman No. 1 filter paper into a 200 ml stoppered conical flask. The above extract was concentrated to 2 ml using a Vigreux fractional distillation column. The concentrated solution was transferred to a screw-capped glass vial and concentrated further by slowly purging nitrogen so as to completely remove the solvent. When not analyzed, the extract in the vial was stored at -18 to -20°C. The amount of the extract was gravimetrically estimated and diluted in n-hexane to an appropriate volume prior to quantification of 2-acetyl-1-pyrroline in the extracts using the method developed by Bhattacharjee *et al*. (2005).

Sensory evaluation

Flavour, colour, and overall acceptability determinations of fresh and dried leaves were made using sensory panel evaluations (nine point hedonic scale). It was speculated that the market value of the product would be influenced by the colour of the leaves where as the aroma and overall acceptability of the cooked rice would establish the consumers preference. Ten number of semi trained panel members were considered for sensing the cooked non aromatic rice added with fresh and dried samples. Average of the scores obtained was calculated and analysed. One aromatic and one non-aromatic variety of rice were included as control samples (two extreme limits).

Microwave drying technique

A programmable domestic microwave oven (LG Intellocook, MC - 8048 WR) with maximum output of 900 W at 2450 MHz was used for the drying experiments. The dimensions of the microwave cavity were 215 mm by 350 mm by 330 mm. The oven had a fan for air flow in the drying chamber and cooling of magnetron. The moisture from drying chamber was removed with this fan by passing it through the openings on the top of the oven wall to the outer atmosphere. The oven was fitted with a glass turntable (314 mm diameter) and had a digital control facility to adjust the microwave output power by the 20% decrements and the time of processing. The microwave oven had the capability of operating at five different microwave output power levels: 180, 360, 540, 720 and 900 W. The fresh leaves with a density of 2.5 kg/m^2 was uniformly spread on the turn-table inside the microwave cavity, for an even absorption of microwave energy. Three replicates were carried out for each experiment according to preset time schedule based on the preliminary tests. Depending on the drying conditions, moisture loss was recorded at 30 sec or 1 min intervals during drying at the end of power-on time by removing the turn-table from the microwave, and periodically placing the leaf sample, on the digital balance (Soysal *et al*., 2006) and the data analysed was an average of these results. The reproducibility of the experiments was within the range of ±5%. All weighing processes were completed in less than 10 s during the drying process. The microwave power was applied until the mass of the sample reduced to a level corresponding to a moisture content of about 0.05 kg of H_2O per kg dry matter.

Analysis of drying data

In order to determine the moisture ratio as a function of drying time, three popular thin layer drying models were used (Table 1). DATAFIT 9.0 (trial version) was used for fitting of the curves into the models. The moisture ratio and drying rate of the *Pandanus* leaves were calculated using the following equations:

$$MR = \frac{M_t - M_e}{M_o - M_e} \quad (1)$$

$$Drying\ Rate = \frac{(M_{t+dt} - M_t)}{dt} \quad (2)$$

Table 1. Mathematical models used to describe the drying kinetic

Name of the Model	Equation	References
Page	MR = exp(- kt^n)	Gupta *et al*., 2002; Yaldiz and Ertekin, 2001; Tulasidas *et al*., 1993; Midilli *et al*., 2002; Kabganian *et al*., 2002; Cronin and Kearny, 1998
Henderson and Pabis	MR = a exp(-kt)	Kabganian *et al*., 2002
Logarithmic	MR = a exp(-kt)+c	Yagcioglu *et al*., 1999; Togrul and Pehlivan, 2002

where MR is the moisture ratio, Drying rate is in g/100 g bone dry matter per unit time, M_t is the moisture content at a specific time (g water / g dry base), M_o is the initial moisture content (g water / g dry basis), M_e is the equilibrium moisture content (g water / g dry basis), M_{t+dt} is the moisture content at t + dt (g water/ g dry base) and t is the drying time (min). The equilibrium moisture content (M_e) was assumed to be zero for microwave drying (Akpinar, 2006; Maskan, 2000; Soysal, 2004).

In general, drying of foods takes place in two periods, a constant rate and a falling rate period. The mode of moisture movement within a hygroscopic solid during the falling rate period could be represented by effective moisture diffusion phenomenon and represents an overall mass transport property of water in the material. During drying it can be assumed that diffusivity explained with Fick's diffusion equation is the only physical mechanism to transfer the water to surface (Dadali *et al*., 2007; Dincer and Dost, 1995; Wang *et al*., 2007). Effective moisture diffusivity which is affected by composition, moisture content, temperature and porosity of the material, is used due to the limited information on the mechanism of moisture movement during drying and complexity of the process (Abe and Afzal, 1997). For the solution of Fick's diffusion equation, the *Pandanus* leave pieces were assumed as a slab. The effective moisture diffusivity was calculated by using the following equation (Crank, 1975):

$$MR = \frac{8}{\pi^2} \sum_{n=0}^{\infty} \frac{1}{(2n+1)^2} \times exp\left(\frac{-(2n+1)^2 . \pi^2 . D_{eff}}{4L^2} t\right) \quad (3)$$

where D_{eff} is the effective moisture diffusivity (m^2 min^{-1}), L is the full thickness of *Pandanus* leaves and t is the drying time (min).

For long drying times; only the first term of the series can be used (Lopez *et al*., 2000; Doymaz, 2006), so the Eq. 3 can be written as:

$$MR = \frac{8}{\pi^2} exp\left(-\frac{\pi^2 . D_{eff}}{4L^2} . t\right) \quad (4)$$

Several researchers have shown that Eq.

4 could be further simplified to a straight-line equation as Eq. 5 (Dadali *et al*., 2007; Wang *et al*., 2007):

$$ln\ (MR) = ln\left(\frac{8}{\pi^2}\right) - \left(\frac{D_{eff}.\pi^2}{4L^2}.t\right) \quad (5)$$

The effective moisture diffusivities are typically determined by plotting experimental drying data in terms of ln(MR) versus time.

The Microsoft Excel 2007 was used in the numerical calculations. The parameters were evaluated by the non-linear least squares method of Marquardt-Levenberg procedure. Reduced chi-square (χ^2), root mean square error (RMSE) and the coefficient of determination (R^2) (Vega-Gálvez *et al*., 2010) were used as the primary criteria to select the best equation to account for variation in the drying curves of the dried samples which are described as follows:

$$\chi^2 = \frac{\sum_{i=1}^{N}(MR_{exp,i} - MR_{pre,i})^2}{N-p} \quad (6)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(MR_{pre,i} - MR_{exp,i})^2}{N}} \quad (7)$$

$$R^2 = \frac{\sum_{i=1}^{N}\left(MR_{pre,i} - MR_{exp,avg}\right)^2}{\sum_{i=1}^{N}\left(MR_{exp,i} - MR_{exp,avg}\right)^2} \quad (8)$$

where $MR_{exp,i}$ is the ith experimental moisture ratio, $MR_{pre,i}$ is the ith predicted moisture ratio, $MR_{pre,\ avg}$ is the average experimental moisture ratio, N is the number of observations, p is the number of constants in the drying model.

Based on the criteria of lowest reduced chi-square and RMSE and highest R^2, the best model describing the thin layer drying characteristics was chosen.

In this study as the temperature was not a measurable variable in the standard microwave oven used for drying process, the Arrhenius equation was used in a modified form to illustrate the relationship between kinetic rate constant and the ratio of the microwave output power to sample amount instead of temperature for calculation of the activation energy. After evaluation of the data, the dependence of the kinetic rate constant on the ratio of microwave output to sample amount was represented with an exponential equation (9) derived by Dadali *et al*. (2007);

$$k = k_0.exp\left(\frac{-E_a.m}{P}\right) \quad (9)$$

where k is the drying rate constant obtained by using Page model (min^{-1}), k_0 is the pre-exponential constant (min^{-1}), E_a is the activation energy (W/g), P is microwave output power (W) and m is the mass of the raw sample (g).

Statistical analysis

Analysis of Variance was carried out for quality characteristics i.e for 2ACPY content and sensory parameters for individual power levels by using the statistical software GENSTAT (Trial version). The significant tests have been carried out from least significant difference (LSD) values.

Results and Discussion

To investigate the effect of microwave output power on moisture content, moisture ratio, drying time, five microwave output powers 180, 360, 540, 720 and 900 W were used for drying of 2.5 kg/m^2 *Pandanus* leaves, as mentioned before. But the drying time at 900 W was only 2 minutes because of which sufficient number of points could not be obtained for further statistical analysis and hence was not included in the analysis work. The moisture content of the material was very high during the initial phase of the drying which resulted in a higher absorption of microwave power and higher drying rates due to the higher moisture diffusion. As the drying progressed, the loss of moisture in the product caused a decrease in the absorption of microwave power and resulted in a fall in the drying rate. The drying rates increased with the increase of microwave power levels. Therefore microwave power level has an positive effect on the drying rates. These results are in agreement with previous studies (Funebo and Ohlsson, 1998; Maskan, 2000; Sharma and Prasad, 2001; Soysal, 2004).

Figure 1 shows the variation of moisture content with respect to the power level. As the microwave output power was increased, the drying time of samples was significantly decreased. The microwave drying process which reduced the moisture content of *Pandanus* leaves from 441.126% (dry basis) to 5.042% (dry basis) took 4-14 min, depending on microwave output power applied. By working at 720 W instead of 180 W, the drying time was shortened by 70%. For comparison of obtained results, no literature is available on drying of *Pandanus* leaves. However, the drying times obtained in the present study were extremely low as compared to the results obtained using different drying methods in the previous studies for different leaves (Akpinar, 2006). The results obtained in the present work showed that as compared to shade drying (2850 min), the drying time could be shortened by (1/200) fold by working at microwave output power of 180 W. Since, the initial moisture contents of *Pandanus* leaves used in drying experiments were constant (441.126% dry basis), the difference in drying time requirements was considered to be mainly due to the difference in the drying rates which are given in Figure 2. After the initial heating, the drying rate of sample was increased to very high values of 282 g/100 g.min at 720 W to 136 g/100 g.min at 180 W. As the microwave output power was increased, the drying rates also increased causing a noticeable reduction in total drying time. This was followed by a falling rate period in which moisture content decreased to about 5.0% dry basis for all microwave output powers. However, these results are in agreement with the study of parsley leaves dried in a domestic microwave oven as reported by Soysal (2004), who claims that after a short heating period, a long constant rate period and a falling rate period were observed. In the present work the initial heating period decreased with increase in output power and the constant rate period is very short in each case. However, careful observation indicates that there is no significant difference in drying rate achieved at 720 W and 540 W.

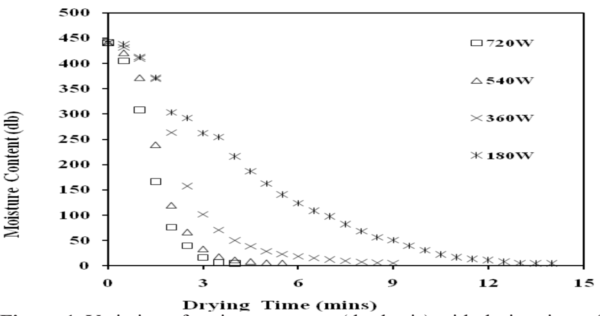

Figure 1. Variation of moisture content (dry basis) with drying time of *Pandanus* leaves at different power levels

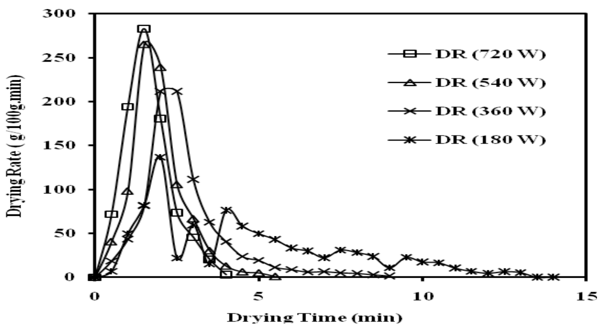

Figure 2. Variation of drying rate with drying time of *Pandanus* leaves at different power levels

Modelling of drying kinetics

Figure 3 shows the decreasing trend of MR with drying time. To describe the effect of microwave output power on the drying kinetics of the *Pandanus* leaves, 3 different semi-empirical thin layer drying models as mentioned in Table 1 were used. Among these models examined, the Page model was observed to be the most appropriate one for all the experimental data with the highest value for the coefficient of determination (R^2) and lowest reduced chi-square (χ^2) and *RMSE*, compared with those obtained for other models. The estimated parameters and statistical analysis of the models examined for the different drying conditions were illustrated in Tables 2 and 3. It was observed that the value of drying rate constant (k) increased with the increase in microwave output power. This implies that with the increase in microwave output power drying curve becomes steeper indicating increase in drying rate. The fitness of the data was illustrated in Figure 4.

Table 2. Modelling of moisture ratio with drying time during microwave drying of *Pandanus* leaves at different power levels

Model	Power level (Watt)	R^2	χ^2	*RMSE*
Page				
	720	0.9983	0.00029	0.01514
	540	0.9932	0.00115	0.03101
	360	0.9884	0.00159	0.03777
	180	0.9946	0.00064	0.02434
Henderson and Pabis				
	720	0.8707	0.02259	0.13254
	540	0.8921	0.01826	0.12336
	360	0.9347	0.00899	0.08968
	180	0.8893	0.01297	0.10988
Logarithmic				
	720	0.9601	0.00813	0.07363
	540	0.9466	0.01005	0.08681
	360	0.9633	0.00538	0.06730
	180	0.9794	0.00250	0.04737

Table 3. Comparison of different drying models with drying constant and coefficient for microwave drying of *Pandanus* leaves at different power levels

Model	Power level (Watt)	Model constants
Page		
	720	k = 0.0975, n = 2.607
	540	k = 0.0709, n = 2.482
	360	k = 0.0540, n = 1.921
	180	k = 0.0058, n = 2.341
Henderson and Pabis		
	720	a = 1.173, k = 0.455
	540	a = 1.196, k = 0.398
	360	a = 1.200, k = 0.260
	180	a = 1.191, k = 0.125
Logarithmic		
	720	a = 9.074, k = 0.033, c = -7.959
	540	a = 2.380, k = 0.122, c = -1.254
	360	a = 1.647, k = 0.131, c = -0.511
	180	a = 8.553, k = 0.010, c = -7.439

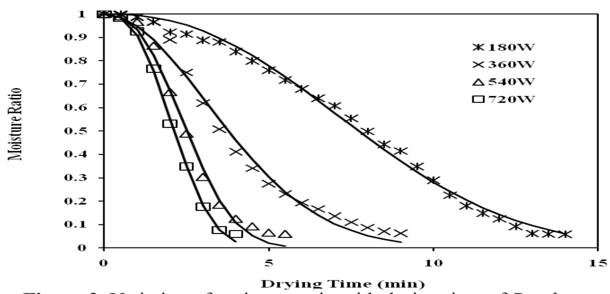

Figure 3. Variation of moisture ratio with drying time of *Pandanus* leaves at different power levels

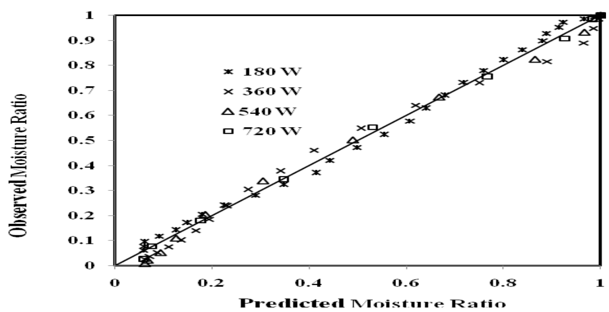

Figure 4. Comparison of experimental and predicted moisture ratio by page model

Moisture diffusivity and activation energy

The effective moisture diffusivity was calculated by using the method of slopes. According to the experimental data obtained at various microwave output power levels, the logarithm of moisture ratio values, ln(MR), were plotted against drying time (t). The linearity of the relationship between ln(MR) and drying time is illustrated in Figure 5 for various output powers (with R^2 more than 0.95 for all the levels). The effective moisture diffusivity values (D_{eff}) for various microwave output powers were calculated and presented in Table 4. The range of moisture diffusivities varied from 5.35E-08 to 1.99E-07 m^2/min. No literature was found out related to the effective moisture diffusivity for *Pandanus* leaves undergoing any drying treatment. However, various research workers have worked on other leaves. Though similar trends were observed, the range of effective moisture diffusivity of *Pandanus* leaves undergoing microwave drying were higher than the values obtained by Akpinar (2006) for different aromatic plants. This may be due to the lower drying times required under microwave treatment.

The values of k versus m/P accurately fit to the exponential model as evident from Figure 6 with coefficient of determination (R^2) of 0.981. Then k_0 was estimated as 0.275 and E_a was determined to be 13.6 W/g and found similar as 12.2839 W/g and 11.0492 W/g, respectively (Dadali *et al*., 2007).

Table 4. Values of effective diffusivity obtained for *Pandanus* leaves at different power levels

Power level (Watt)	Effective Diffusivity (D_{eff}) (m^2/ min)
180	5.35E-08
360	8.83E-08
540	1.55E-07
720	1.99E-07

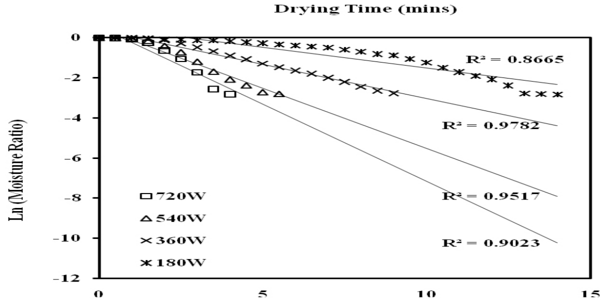

Figure 5. Linear relationship between ln(mr) and drying time at various microwave output power levels

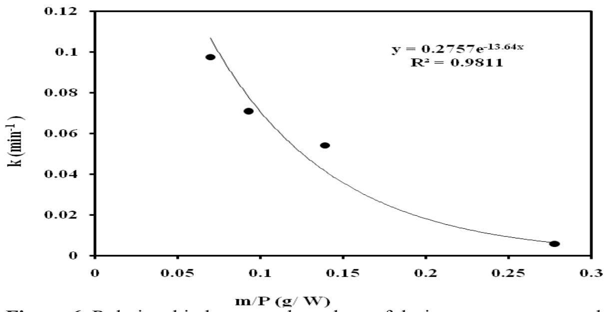

Figure 6. Relationship between the values of drying rate constant and ratio of sample amount to microwave power

Effect of power level on aromatic compound (2-Acetyl-1-pyrroline) and sensory evaluation

From Table 5 it was observed that the 2-acetyl-1-pyrroline content decreased with increase in microwave output powers because of its temperature sensitivity. The retention of 2-acetyl-1-pyrroline content was more and not significantly different in samples dried at 540 and 360 W output power. But 2-acetyl-1-pyrroline content of samples dried at 180 W was found to be less than that obtained at 360 W. This may be due to the relatively long drying time (14 min) requirement, which facilitated for removal of volatile compounds. The mean sensory scores for different quality attributes of dried leaves are also presented in Table 5. The sensory attributes were almost same for aromatic rice and non aromatic rice when cooked with fresh leaves. The color of microwave dried samples was observed to be significantly better as compared to that of the shade dried samples. The microwave output power level except 180 W did not have any significant effect on color of the dried products. These results are consistent with those of Ozkan *et al*. (2007). They investigated the colour change in spinach leaves at microwave powers of 90 to 1000 W and determined the lowest colour change at 750 W microwave powers. According to Schiffmann (1995), high moisture bio-products undergoing microwave drying have the advantage. Microwave drying pushes liquid into the surface and the liquid is usually converted into the vapour. This process results in drying without causing surface overheating phenomena. Therefore, in terms of surface colour degradation, preservation of the product colour was good. It is estimated that the products are subjected to high temperature with the increasing power levels during microwave drying. Therefore, the product colour is adversely affected in the drying processes at very high microwave powers (Ozkan *et al*., 2007). In the present study, the relatively low sensory scores in colour at 720 and 900 W microwave power are supported by the results obtained in the previous research above. From the organoleptic evaluation (aroma, and overall acceptability score) of dried samples, it was observed that the samples at lower microwave output powers were preferable product. However, it was also observed that the samples dried at 540 W, fetched highest sensory score and there was no significant difference in all these quality parameters obtained at 360 W. But the drying rates achieved at 360 W is less and hence the drying time requirement is more. On the contrary, though the drying rates achieved at 540 and 720 W are very close, there was a significant reduction in quality parameters in samples dried at 720 W. Hence, considering the drying characteristics and the retention of quality parameters, drying at 540 W may be preferable.

Table 5. 2-Acetyl-1-pyrroline content and sensory evaluation of leaves dried by different means

	2-acetyl-1-pyrroline ppm	Colour of leaf	Aroma	Overall acceptance
Non aromatic rice	0.064^{g}	-	-	-
Fresh	0.882^{a}	9.0^{a}	9.0^{a}	8.5^{ab}
Shade dried	0.588^{de}	6.0^{d}	7.5^{c}	6.0^{e}
Microwave				
900W	0.466^{f}	8.0^{bc}	4.0^{d}	5.0^{f}
720W	0.529^{e}	8.0^{bc}	7.5^{c}	7.2^{d}
540W	0.746^{b}	8.5^{ab}	8.5^{ab}	8.5^{ab}
360W	0.714^{bc}	8.2^{b}	8.2^{b}	8.2^{bc}
180W	0.664^{cd}	7.5^{c}	7.5^{c}	7.5^{cd}
Aromatic rice	0.885^{a}	-	9.0^{a}	9.0^{a}

* Superscripts with the same letter in a same column are not significantly different at a probability, $P<0.05$.

Conclusion

Hence, it can be concluded that in the case of *Pandanus* (*Pandanus amaryllifolius*) leaves drying time decreased considerably with increase in microwave output power and this technique can be successfully used to dry *Pandanus* leaves as compared to shade drying, with maximum preservation of aroma. After the initial heating period, the process attained very high drying rates followed by the falling rate period during which maximum drying took place and maximum drying rates were about 282 g/100 g.min at 720 W to 136 g/100 g.min at 180 W. Among the three models proposed to describe the drying kinetics of *Pandanus* leaves, the semi-empirical Page model provided a good agreement between experimental (observed) and predicted moisture ratio values with higher coefficients of determination and lower reduced chi-square (χ^2) and *RMSE* values. The value of the drying rate constant, *k*, increased with the increase in microwave output power and a linear relationship was obtained between the data of ln(MR) and drying time (t). For constant amount of 2.5 kg/m^2 fresh sample, the effective moisture diffusivities varied from 5.35E-08 to 1.99E-07 m^2/min with the increase in microwave output power. Comparison of aromatic compound (2-acetyl-1-pyrroline) in *Pandanus* leaves showed declining trend with increase in microwave output power from 720 W. There was no considerable difference in drying rate achieved at 720 W and 540 W and retention of aromatic compound was more at the lower power level. So keeping in view both the drying time and sensory attributes of the leaves, microwave drying of the leaves at 540 W may be proposed, to obtain an acceptable product.

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