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Drying Characteristics of Malaysian Padi

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ABSTRAK

Dalam karya ini, kelakuan pengeringan padi Malaysia dikaji dengan menggunakan kaedah lapisan nipis. Lengkung pengeringan cirian padi ditentukan dengan menggunakan kebuk sekitaran. Uji kaji meliputi suhu udara antara 30°C hingga 70°C, kelembapan udara 30% hingga 80% dan halaju udara 0.12 hingga 1 m/s. Tempoh kadar malar tidak dicerap. Kehilangan jisim, suhu, kelembapan nisbi, dan halaju udara diawasi melalui komputer peribadi. Lengkung pengeringan menunjukkan dua tempoh kadar menurun, iaitu tempoh pengeringan awal yang laju dan seterusnya tempoh pengeringan yang perlahan. Kadar pengeringan ternormal melawan kandungan lembapan ternormal diregresikan dengan kaedah ganda dua terkecil untuk memadankan model polinomial baru untuk tempoh kadar menurun pertama dan model linear untuk tempoh kadar menurun kedua Model-model ini menganggar kedua-dua tempoh kadar menurun dengan baik.

ABSTRACT

In this paper, the drying behaviour of Malaysian padi was studied using the thin layer method. Characteristic drying curves of padi were determined using an environmental chamber. The experiments were conducted over a temperature range of between 30°C to 70°C, air relative humidity from 30% to 80% and air velocity from 0.12 to 1 m/s. No constant rate periods was observed. Mass loss, temperature, relative humidity and air velocity were monitored on a personal computer. From the drying curves, two falling rate periods were observed, namely an initial rapid drying period and a subsequent gradual drying period. The normalised drying rate versus normalised moisture content was regressed by least square method to fit a new polynomial model for the first falling rate period and a linear model for the second falling rate period. Both the polynomial and linear models estimate the falling rate periods quite well.

Keywords: Drying kinetics; thin layer method, characteristic drying curve

INTRODUCTION

Artificial drying of biological products such as padi, is one of the common methods of preservation. Proper drying procedures can eliminate the potential of spoilage during subsequent storage and the product quality can thus be improved. However rapid drying can increase brittleness and induce internal cracks which predispose the product to breakage during subsequent handling, and reducing its quality. The drying process must be understood and controlled model is proposed. The general polynomial given by the following equations is proposed as the new form of the curve:

$$g = \sum_{n=0}^{n} A_n \mu^n \qquad B < \mu < 1 \tag{10}$$

$$g = C\,\mu^m \qquad 0 < \mu < B \tag{11}$$

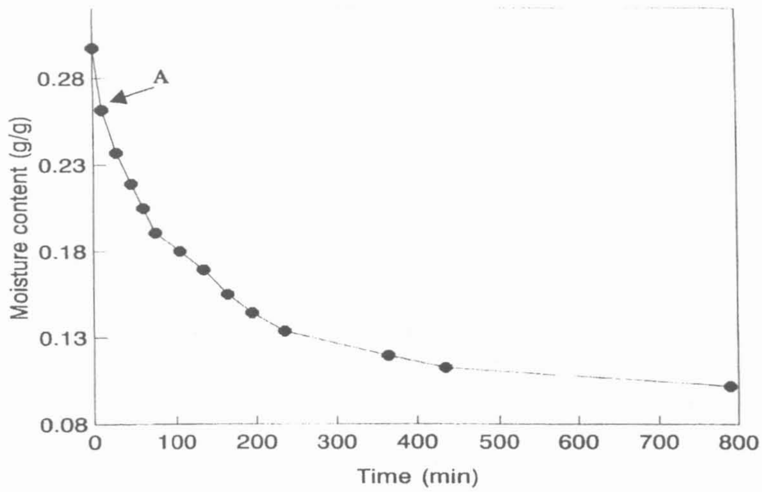

Fig 1. *Time versus mass loss for padi at condition A1 indicating initial moisture content X_0 = 0.2969 (g/g), temperature T= 40°C, relative humidity RH = 45% and air velocity u = 0.96 m/s*

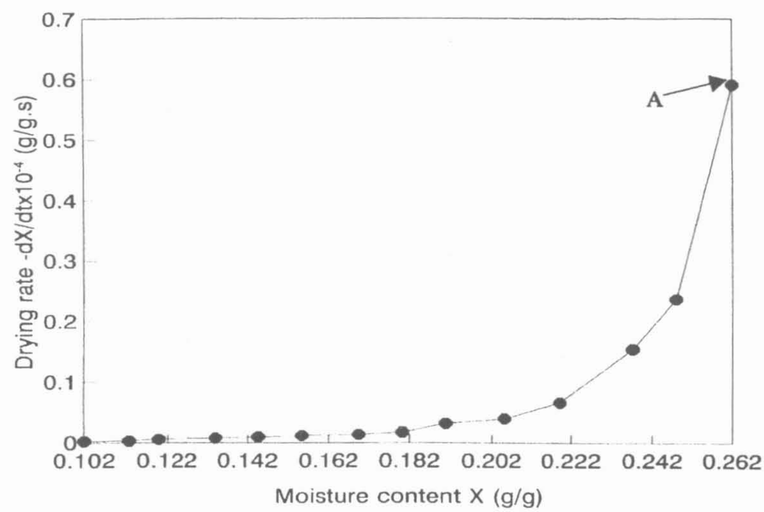

Fig 2. *Moisture content (X) versus drying rate (-dX/dt) for padi at condition A1. X_{ind} = 0.2969*

MATERIALS AND METHODS

Freshly harvested padi was collected from Tanjung Karang, Selangor, Malaysia. The sample was preserved in a container at 0°C temperature until used. No appreciable loss in mass was detected after the sample was thawed before use. The initial moisture content of the sample ranged from 23.6 % to 35.93 % (dry basis). The drying data were measured using an environmental chamber (μ-Isuzu). The environmental chamber can produce air velocity ranging from 0.12 m/s to 0.96 m/s, humidity range of 20 to 90% and temperature range of 20°C to 70°C. The actual operating conditions for the various experimental runs are given in Table 1. The variation of temperature and relative humidity in the chamber were ± 0.5°C and ± 3.0% respectively. A single layer padi was suspended by a balance from a Mettler AT250 electronic balance in the test section. Mass loss of the balance was monitored on a microcomputer connected to the balance via RS port, by using a data acquisition software. The temperature, relative humidity and velocity of the air were monitored on a microcomputer using a software SOLOMAT 4000 data acquisition system. Initial moisture content of the samples was determined according to the IDRC-053e, where two to five grams of the sample were grounded and weighed in a weighing bottle. The powdered sample was placed in an electric oven for 5 hours at a temperature of 130°C. It was then allowed to cool inside a dessiccator before weighing.

TABLE 1
Operating conditions of environmental chamber

Run No.	Initial Moisture content (g/g)	Air Temperature (°C)	Relative Humidity (%)	Air Velocity (m/s)
A1	0.2969	40	45	0.96
A2	0.2905	50	35	0.96
A3	0.2945	50	40	0.96
A4	0.2579	60	30	0.96
A5	0.2753	60	43	0.96
A6	0.2377	70	32	0.96
A7	0.2510	70	41	0.96
A8	0.2361	70	50	0.96
B1	0.3213	50	40	0.46
B2	0.2875	60	30	0.46
B3	0.2360	70	50	0.46
C1	0.2904	40	51	0.12
C2	0.3593	50	44	0.12
C3	0.3059	60	35	0.12
C4	0.3007	60	50	0.12

RESULTS AND DISCUSSION

One set of the experimental results is shown in *Figs. 1* and *2*. It is clearly evident from *Fig. 2* that the whole drying process is a falling rate drying period. The constant rate period is non-existent and the falling rate period can be divided into two. Period I is the shortest period and during this period, the drying rate decreases sharply. In period II, drying advances very slowly and the grains reach the equilibrium moisture content at the end of the drying.

The drying data are normalised using X_e value derived from padi desorption data. The normalised data are regressed by least square method according to Equation (8) up to third order and Equation (9) with the exponent m equal to unity to account for the linearity of the regular regime period. The results of the normalisation and regression are shown in Table 2 and in *Figs. 3, 4, 5, 6, 7* and *8*. The polynomial model estimates the characteristic drying curve quite well whereas the regular regime is found to be linear.

Once the data have been normalised and fitted to Equations (8) and (9) as described above, the reduced characteristic curves all fall into a tight band, indicating that the effect of variation in different conditions is small over the range tested. This trend is shown clearly in *Fig. 3* to *8*. The location of the second critical point in the normalised moisture content is determined by a discontinuity in slope and ranges from $B = 0.242$ to $B = 0.732$. The slope of the regular regime increases slightly with air velocity indicating a faster drying rate for higher velocities. The minimum effects of operating conditions on the

TABLE 2

Regression analysis of the characteristic drying curves of padi

Run No.	Induction drying rate (x10^{-4} kg/kg dry matter s)	A_o	A_1	A_2	Regression Coefficient R^2	Second Critical Point (kg/kg)	Second Critical Point B	C	Regression Coefficient R^2
A1	0.598	1.9525	-6.5031	5.5176	0.982	0.192	0.732	0.0617	0.9640
A2	1.010	2.2213	-5.6785	5.9876	0.9721	0.179	0.688	0.0338	0.9430
A3	0.799	2.3106	-7.1934	5.8464	0.9231	0.135	0.573	0.0617	0.9150
A4	1.575	1.1869	-6.3791	5.4405	0.9627	0.130	0.607	0.0437	0.8796
A5	1.033	1.1464	-4.4938	4.2605	0.9610	0.130	0.527	0.0391	0.912
A6	1.280	0.4696	-2.0252	2.5533	0.9985	0.090	0.495	0.1105	0.9053
A7	1.240	0.7749	-3.0775	3.2854	0.9933	0.067	0.340	0.0601	0.9695
A8	1.502	0.7705	-3.1471	3.3534	0.9918	0.068	0.376	0.0685	0.8588
B1	0.775	0.6081	-2.6515	2.974	0.977	0.158	0.612	0.044	0.9548
B2	1.601	0.776	-3.3401	3.4549	0.9488	0.110	0.455	0.0299	0.9193
B3	1.302	0.5091	-2.4025	2.8537	0.9836	0.090	0.501	0.0438	0.9234
C1	0.960	0.9575	-3.9007	3.8185	0.9331	0.135	0.523	0.0205	0.8756
C2	0.803	0.5441	-2.6014	2.8933	0.9128	0.120	0.355	0.0274	0.9533
C3	1.980	0.7713	-3.2808	3.4267	0.9592	0.060	0.242	0.0327	0.9600
C4	1.240	0.442	-2.2778	2.7452	0.954	0.064	0.246	0.0273	0.9754

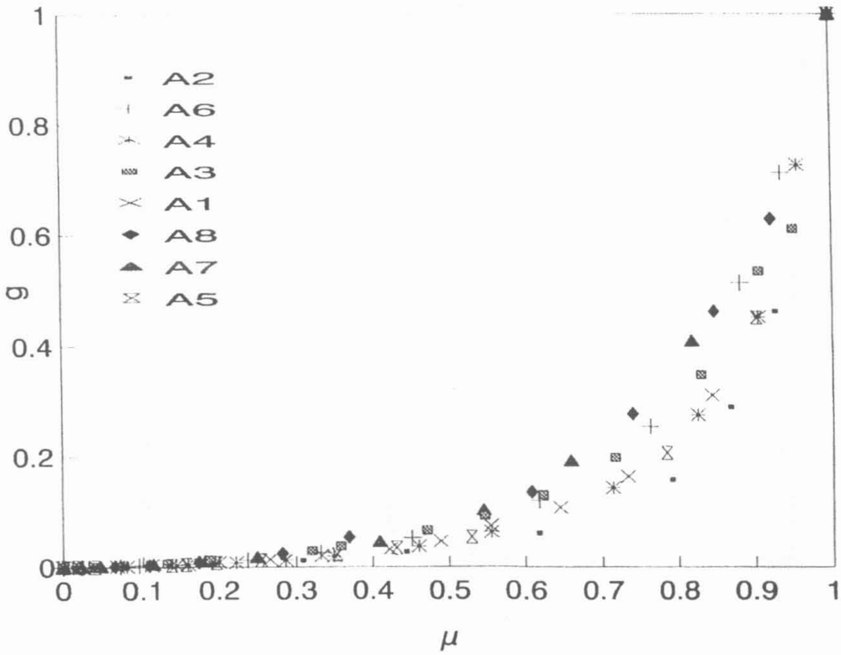

Fig 3. Normalised drying rate versus normalised moisture content for air velocity 0.96m/s

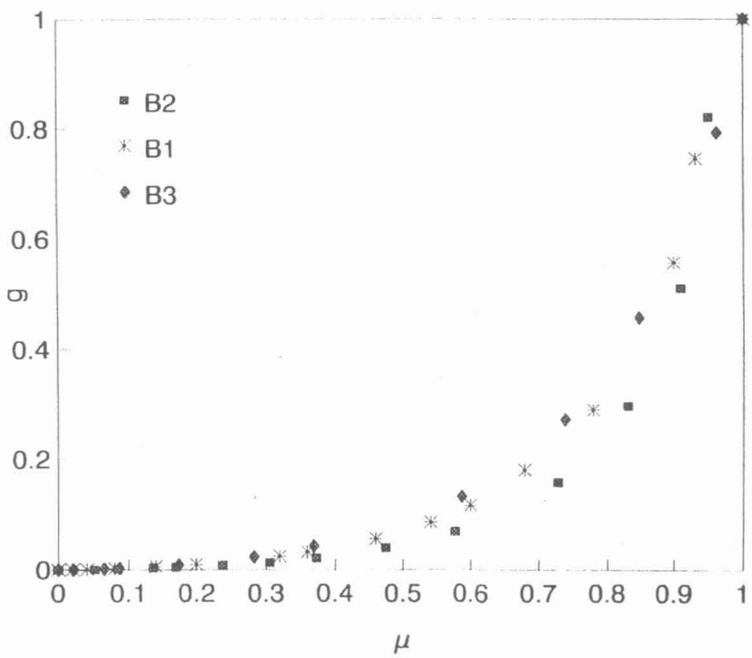

Fig 4. Normalised drying rate versus normalised moisture content for air velocity 0.46m/s

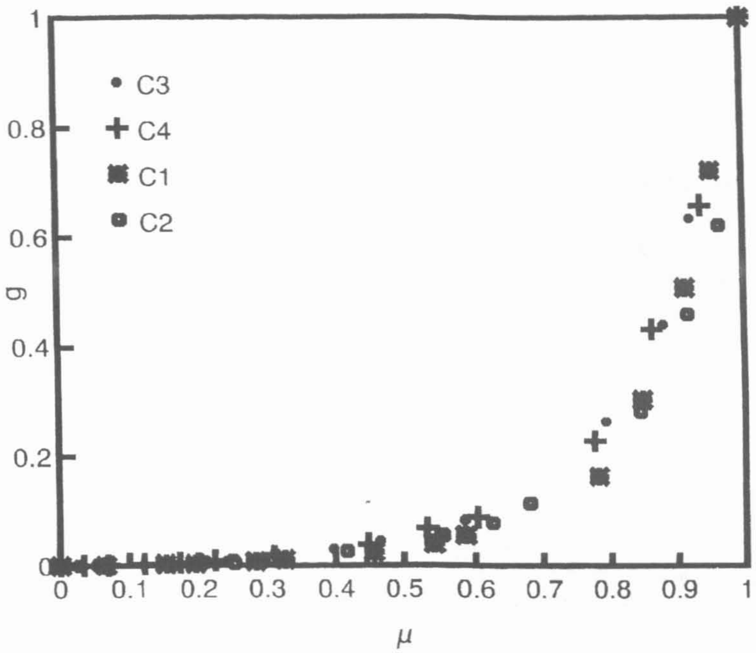

Fig 5. Normalised drying rate versus normalised moisture content for air velocity 0.12m/s

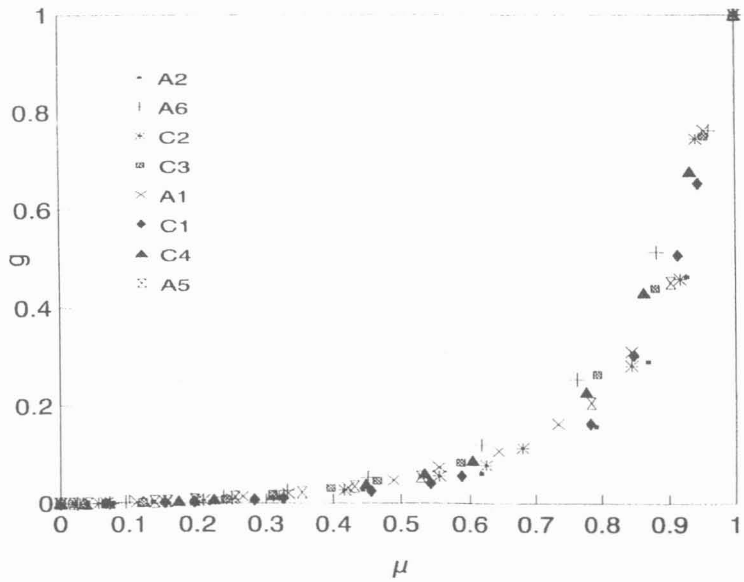

Fig 6. Normalised drying rate versus normalised moisture content for air velocity 0.96m/s and 0.12m/s.

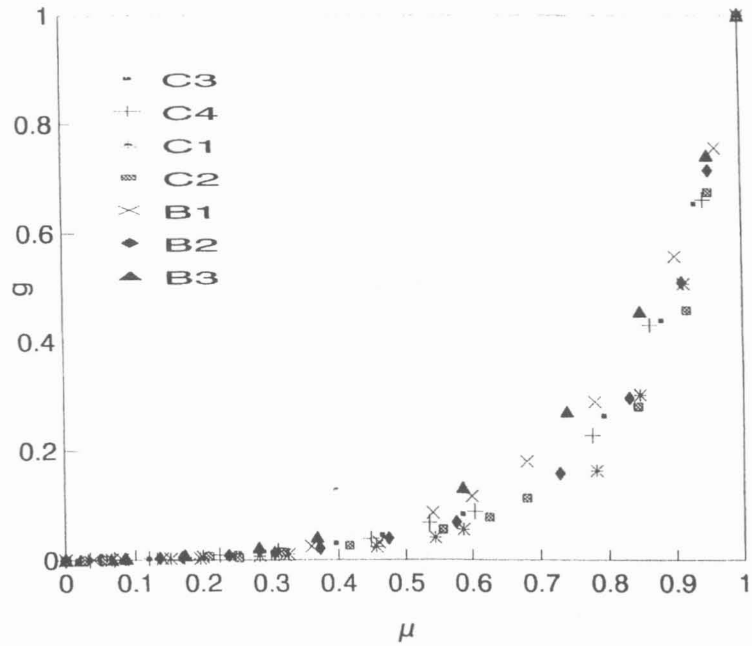

Fig 7. Normalised drying rate versus normalised moisture content for air velocity 0.46m/s and 0.12m/s.

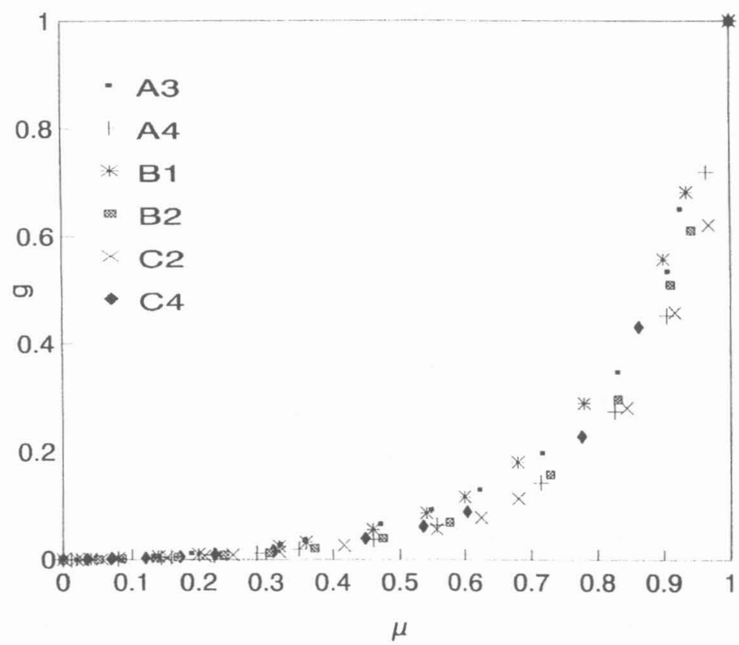

Fig 8. Normalised drying rate versus normalised moisture content for air velocity 0.96m/s , 0.46m/s and 0.12m/s

normalised curves confirm the existence of a characteristic drying curve for thin layers of padi.

CONCLUSION

It is concluded that in the characteristic drying curve of Malaysian padi, there are two falling rate periods, namely an initial rapid drying period and a slow drying period. The polynomial model estimates the falling rate period quite well whereas the regular regime was found to be linear. It is significant that the curves are unaffected by small variations in depth and uniformity of particle layers. This means that the curves are free from minor operating errors in arranging the layers. The thin layer technique is thus a robust way of determining the characteristic drying curve of padi. It is further concluded that the concept of the characteristic drying curve is also valid for the thin layer drying of padi.

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NOTATION

A, B, C	Parameters of characteristic function	
f	Characteristic drying rate	-
g	Reduced characteristic drying rate	-
X	Moisture content (Decimal)	kg/kg
N_{max}	Maximum average drying rate	kg/kg s

Greek letters

Φ	Characteristic moisture content
Φ_1	Characteristic moisture content at the end of induction period
μ	Reduced characteristic moisture content

Subscripts

cr	Critical
e	Equilibrium
ind	At the end of induction period

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