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Studies on Effect of Slice Thickness and Temperature on Drying Behaviour of Kothimbda (Cucumis Callosus)

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Abstract

The Kothimbda slice was dried in Industrial tray dryer with three levels of drying temperature (50, 60 and 70 °C) and three levels of thickness (3mm, 5mm and 7 mm). The air velocity was kept constant at 1.5 m/sec throughout the experiment. Besides mechanical drying the slices of 3, 5 and 7 mm thickness were dried in solar cabinet dryer also. The observations on reduction in weight were taken regularly with increase in time and were evaluated in terms of drying characteristics. Three drying models i.e. Page, Henderson and Pabis and Logarithmic were tested for their validity. The values of coefficient of determination (r2) for all the three models under all the treatments were found to be above 0.9, suggesting good fit of the observations. Though, the value of r2 under the Logarithmic Model was more followed by page and Henderson and Pabis, indicating the Logarithmic model more reliable for prediction and found best fitted. For all the drying treatments taken the value of drying constants a, k and c under Logarithmic Model was varying from 0.00018 to 0.00233, 1.17 to 1.66 and -0.05244 to 0.01749 respectively

Keywords: Experiential Learning, Simulation, Nutrition Support, Critical Care, Medical Nutrition Therapy

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Introduction

Cucumis callosus (Rottl.) Cogn (Cucurbitaceae) is very common throughout the India and commonly known as "Kothimbda" in Gujarat. The mature fruits of *Cucumis callosus (rottl.) Cogn (Kothimbda)*, a drought tolerant cucurbitaceous vegetable found growing abundantly during rainy season in the arid and semiarid regions of North-Western India, particularly in Gujarat and Rajasthan, are usually cooked with various vegetable preparations. It is an ideal summer vegetable crop chiefly grown for its edible tender fruits, preferred as salad ingredient, pickles, Desert fruit and as a cooked vegetable. The ripe fruits are eaten as such, while unripe fruits used as vegetable. Fruits are known to contain vitamin C (Singh and Joshi, 2010).

Kothimbda powder obtained after drying the fruits is used as souring agent in combination with other spices to make spice premix and mouth fresheners. Powder of *Kothimbda* with other spices is commonly used for various therapeutic purposes to cure stomach pain, nausea, vomiting and constipation. The dehydrated *Kothimbda* is coughicide, vermicide, cooling, diuretic and gastric stimulant. Amongst all nutrients Ascorbic acid (Vitamin c) is most important from the processing point of view (Goyal and sharma, 2009).

The post-harvest loss of Kothimbda varies from 30 to 40 per cent due to its perishable nature and glut during harvesting time, which also reduces the market value of the fruit. Hence, dehydration is the only solution to overcome the problem of post-harvest losses as well as to provide high returns to the growers along with the availability of the fruit during off season. The farmers producing Kothimbda of our country are still using the traditional drying techniques for drying of Kothimbda and so far very little scientific research work has been undertaken on standardization of drying and dehydration technology especially for Kothimbda. Appropriate size of slices and drying temperatures are good for drying and improve the appearance, colour and quality of dehydrated product.

Generally, fruits and vegetables are heat sensitive and therefore present a special problem when drying. Dehydration has to be carried out under carefully controlled conditions. Sun drying is being increasingly adopted in vegetable preservation due to high cost skill required in the artificial drying method. The rate of drying depends upon the rate of humidity and size or thickness of the pieces. The range of drying is determined by a range of factors such as external air, temperature, the size of the food pieces been dried and the depth to which the drying tray is packed. Since these factors vary, it is impossible to give an exact drying time for any particular food item. Considering all above aspects in mind a Research was undertaken to studied the drying characteristics of *kothimbda (cucumis callosus*

Materials And Methods

The fresh Kothimbda (Cucumis callosus) were procured from a progressive farmer's field located at village Dhava (Ta.: Talala Dist.: Gir Somnath). The fruits were immediately transferred to laboratory. Subsequently, Kothimbda fruits were thoroughly washed with fresh water to remove adhered earth and other foreign materials. Thereafter, the fruits were spread in the shade to remove surface moisture accumulated during washing. The fruits thereafter were sorted to eliminate damaged, soft and immature fruits. The sound and uniformly matured fruits without any damage were selected for the experiment.

The washed and shade dried Kothimbda fruits were sliced into 3 mm, 5 mm and 7 mm thickness by using stainless steel knife. To prevent bacterial/mold infection, the knifes were frequently dipped into potassium permanganate solution (5%) for 2 minutes before reusing for slicing. The slices of Kothimbda Slices were uniformly spread in single layer in tray for dehydration.

Initial Moisture content

Moisture content was estimated using gravimetric method. The weight of glass petri dish having a tight fitting cover was noted. Approximately, 5-10 g of sample was placed in it and weight was noted accurately. Thereafter, sample was dried in a hot air oven (SCIENTRONIC UNIVERSAL OVEN, Model No. SOM45) for 3 hours at 100 °C (and increasing the temperature to 105- 110 °C during the final heating period to expel last traces of occluded water). After drying, dish was removed and cooled in desiccator and weighed. It was re dried for 1 hour and the process was repeated until change in weight between successive weighing at 1 hour intervals did not differ by 0.1 to 0.2 mg (Ranganna, 1979).

$$\%\ moisture = \frac{loss\ in\ weight\ on\ drying \times 100}{weight\ of\ sample\ taken} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Drying Characteristics of Kothimbda

Moisture content

Moisture content of Kothimbda fruits during experiment was determined on the basis of dry matter of Kothimbda.

Dry matter

Percent dry matter in a sample was calculated as following:

DM (%, dry matter) = 100.0 – [MC (% w.b.)] ……....…… (2)

DM (g, dry matter) = Total mass of sample (g) – mass of moisture in sample (g) ………… (3)

Drying rate

The moisture content data recorded during experiments were analysed to determine the moisture lost in the representative sample in particular time interval. The drying rate of the samples was then calculated by equation,

$$DR = \frac{Initial\ weight\ of\ sample, g - Weight\ of\ sample\ after\ time\theta, g}{Time\ interval, h \times Dry\ matter, g} \ldots\ldots\ldots\ldots\ldots (4)$$

V

DR = Drying rate at timeθ g of water removed/g of dry matter in unit time (h)

Equilibrium moisture content

Equilibrium moisture content was calculated taking any two successive observations of moisture content Mn and Mn+1, % w.b. and their corresponding drying times tn and tn+1 and fitting in the following equation (Singh et al., 1986).

$M_n = z^* M_{(n+1)} + (1-z) M_e$………….(5)

Where,

$z^* = \exp(k\Delta t)$, and $\Delta t = t_n - t_{n+1}$

Me = equilibrium moisture content, % w.b.

k = drying constant

The equilibrium moisture content calculated using above expression was found much above than the final moisture content and therefore the final moisture content was considered as equilibrium moisture content (Prabhanjan et al., 1995).

Overall drying rate

The overall drying rate was calculated as (Kar and Gupta, 2003),

$(\delta M/\delta t)_o = ((M_i - M_f))/\Delta t$ ....(6)

Where, $(\delta M/\delta t)_o$ = overall drying rate, 1/min.

Mi = initial moisture content, % w.b.

Mf = final moisture content, % w.b.

Δt = total drying time, min.

Moisture ratio

Moisture ratio for the individual drying experiment under each drying method was estimated using equation and they are used for showing drying phenomena

$MR = (M - M_e)/(M_i - M_e)$……………… … (7)

Where,

Mi = moisture content of sample at time θ = 0

M = moisture content of sample at any instant time

Me = Equilibrium moisture content

Model Validation

The following commonly used grain models were tested for their validity on *Kothimbda* drying:

No.	Model Name	Equation	Reference
1	Page Model	MR = exp(-ktn)	Page GE (1949)
2	Henderson & Pabis model,	MR = a exp(-kt)	Henderson SM, Pabis S, (1991)
3	Logarithmic Model,	MR = a exp(-kt) + c,	Abano et al. (2011)

a, c, k and n are constant for different drying models

Three primary criteria were used to determine the goodness of fit to the models; the correlation coefficient (r2), the root mean square error (RMSE) and the reduced chi-square (χ2). The highest r2, lowest χ2 and RMSE will be used to determine the goodness of fit (Abano et al. 2011). . The observations on drying were analysed by Microsoft Office Excel, Curve Expert - Origin (nonlinear regression analysis).

Results And Discussion

Drying Behaviour of Kothimbda

Mechanical dying

50 °C drying temperature with three levels of thickness (3mm, 5mm and 7mm)

Initial moisture content of Kothimbda fruit was 91.89 % (w.b.). The time required for drying of Kothimbda fruit at 50 °C drying temperature to final moisture content of about 3.5 % (w.b.) was 500, 540 and 600 min. for 3mm, 5mm and 7 mm slice thickness, respectively. The initial drying rate was of the order of 2.44, 2.90 and 1.94 g of water removed /g of dry matter - h, which reduced to 0.002, 0.003 and 0.002 g of water removed /g of dry matter - h, after 500, 540 and 600 min. of drying, under hot air oven with 3mm, 5mm and 7 mm slice thickness, respectively.

60 °C drying temperature with three levels of thickness (3mm, 5mm and 7mm)

When it dried at 60 °C drying temperature to get final moisture content (w.b.), time required for drying of Kothimbda fruit were 400, 400 and 460 min. for 3mm, 5mm and 7 mm slice thickness, respectively. The initial drying rate was of the order of 4.33, 5.19 and 1.98 g of water removed /g of dry matter - h, which reduced to 0.028, 0.04 and 0.14 g of water removed /g of dry matter - h, after 400, 400 and 460 min. of drying, under hot air oven with 3mm, 5mm and 7 mm slice thickness, respectively.

70 °C drying temperature with three levels of thickness (3mm, 5mm and 7mm)

When it dried at 70 °C drying temperature to get final moisture content (w.b.), time required for drying of Kothimbda fruit were 342, 342 and 552 min. for 3mm, 5mm and 7 mm slice thickness, respectively. The initial drying rate was of the order of 6.64, 4.28 and 2.69 g of water removed /g of dry matter - h, which reduced to 0.54, 0.11 and 0.05 g of water removed /g of dry matter - h, after 342, 342 and 552 min. of drying, under hot air oven with 3mm, 5mm and 7 mm slice thickness, respectively.

The *Kothimbda* dried at 70 o C took considerably lower time to reduce the moisture content from about 93% to 3.5% (w.b.). Obliviously, at higher temperature the movement of drying front was faster as compared to lower temperature. Similar results are reported by Kabiru et al. (2013) for drying of mango slice, Islam et al. (2012) for green banana, Limpaiboon (2011) in case of pumpkin slice and Abano et al. (2011) for drying of tomato slices.

No.	Temp. °C	Thickness, mm	k	n	r^2	χ^2
1	50	3	0.00108	1.30110	0.99437	0.00072
2		5	0.00146	1.24851	0.99636	0.00042
3		7	0.00146	1.16225	0.98109	0.00227
4	60	3	0.00173	1.30629	0.99697	0.00044
5		5	0.00287	1.19627	0.99278	0.00098
6		7	0.00074	1.26704	0.98956	0.00116
7	70	3	0.00292	1.23202	0.99411	0.00087
8		5	0.00186	1.32904	0.99543	0.00072
9		7	0.00076	1.35518	0.99263	0.00112
10	Solar drying	3	0.00031	1.55111	0.99710	0.00039
11		5	0.00040	1.36638	0.99421	0.00073
12		7	0.00058	1.26225	0.98464	0.00176

Table 1: Statistical result of Page Model(MR = exp(-ktn)) drying models for different slthickness of Kothimbda fruit.

No.	Temp., °C	Thick., mm	a	k	COD, R^2	X^2
1	50	3	1.06734	0.00571	0.97381	0.00337
2		5	1.05439	0.00574	0.98604	0.00161
3		7	1.06141	0.00388	0.96820	0.00381
4	60	3	1.05321	0.00821	0.98359	0.00237
5		5	1.02792	0.00778	0.98500	0.00204
6		7	1.04506	0.00344	0.97255	0.00306
7	70	3	1.02792	0.00778	0.98500	0.00204
8		5	1.04196	0.00926	0.98040	0.00310
9		7	1.07233	0.00535	0.97144	0.00434
10	Solar drying	3	1.08155	0.00608	0.97049	0.00393
11		5	1.07116	0.00359	0.97559	0.00308
12		7	1.05043	0.00283	0.96891	0.00356

Table 2: Statistical result of Henderson & Pabis model (MR = a exp(-kt)) drying models for different slice thickness of Kothimbda fruit.

No.	Temp., °C	Thick.,mm	a	k	c	COD, R^2	X^2
1	50	3	0.00060	1.40606	-0.02260	0.99798	0.00083
2		5	0.00153	1.22055	-0.02810	0.99761	0.00030
3		7	0.00048	1.33031	-0.05244	0.99203	0.00381
4	60	3	0.00156	1.31088	-0.02320	0.99822	0.00029
5		5	0.00209	1.23733	-0.03289	0.99535	0.00071
6		7	0.00102	1.17926	-0.04540	0.98446	0.00192
7	70	3	0.00233	1.25701	-0.03181	0.99613	0.00065
8		5	0.00164	1.33870	-0.02338	0.99647	0.00064
9		7	0.00052	1.40123	-0.03764	0.99623	0.00063
10	Solar drying	3	0.00018	1.66273	0.00967	0.99830	0.00025
11		5	0.00023	1.48031	0.01749	0.99007	0.00137
12		7	0.00041	1.30287	-0.02658	0.98610	0.00174

Table 3: Statistical result of Logarithmic Model (MR = a exp(-kt) + c) drying models for different slice thickness of Kothimbda fruit.

Solar drying

Solar drying twith three levels of thickness (3mm, 5mm and 7mm)

The freshly harvested Kothimbda fruit slices were placed in the solar cabinet dryer for drying. The average temperature inside the dryer was varied from 34 to 72 o C during the sunlight hours for complete period of experimentation. The observations on weight loss were recorded at an interval of 1 hour initially and subsequently at 2 hours.

When it dried in solar dryer to get final moisture content (w.b.), time required for drying of Kothimbda fruit were 11, 13 and 11 h. for 3mm, 5mm and 7 mm slice thickness, respectively. The initial drying rate was of the order of 1.71, 1.12 and 0.94 g of water removed /g of dry matter - h, which reduced to 0.04, 0.05 and 0.42 g of water removed /g of dry matter - h, after 11, 13 and 11 h. of drying, under hot air oven with 3mm, 5mm and 7 mm slice thickness, respectively.

The variation in moisture content and drying rate with respect to time (Fig. 1, 2,3,4) was observed to be curvilinear in nature, suggesting that drying proceeded under falling rate. The nature of variation of these parameters also indicated that the drying rate and removal of moisture with respect to time was initially rapid, and decreased thereafter in all cases.

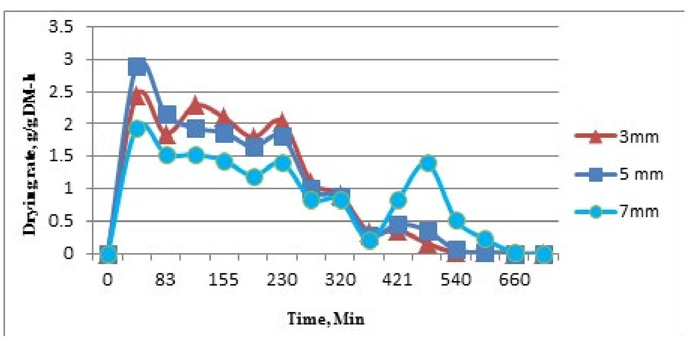

Figure 1: Variation in drying rate with time (50 °C Air temperature).

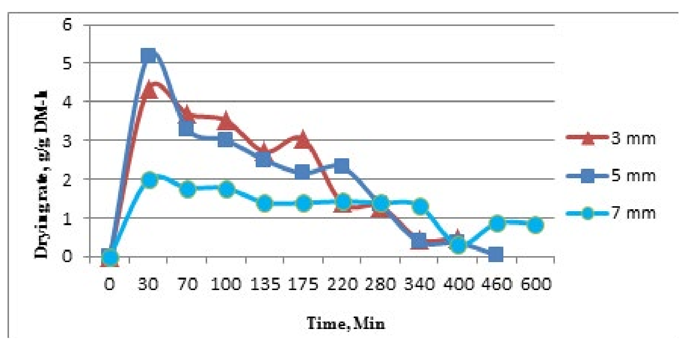

Figure 2: Variation in drying rate with time (60 °C Air temperature).

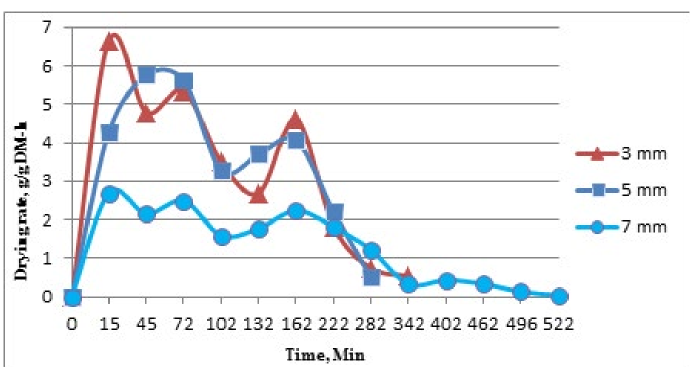

Figure 3: Variation in drying rate with time (70 °C Air temperature).

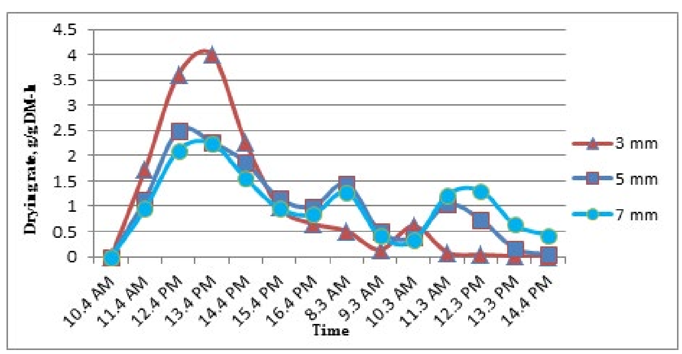

Figure 4: Variation in drying rate with time (Solar dried).

The observations taken during all the drying treatments were fitted to Henderson and Pabis, Page and Logarithmic model and the predicted equations were also determined (Fig. 5-16). The values of coefficient of determination (r2) for all the three models under all the treatments were found to be above 0.9, suggesting good fit of the observations. Though, the value of r2 under the Logarithmic Model was more followed by page and Henderson and Pabis, indicating the Logarithmic model more reliable for prediction and found best fitted. The values of constants of different models are given in Table 1-3.

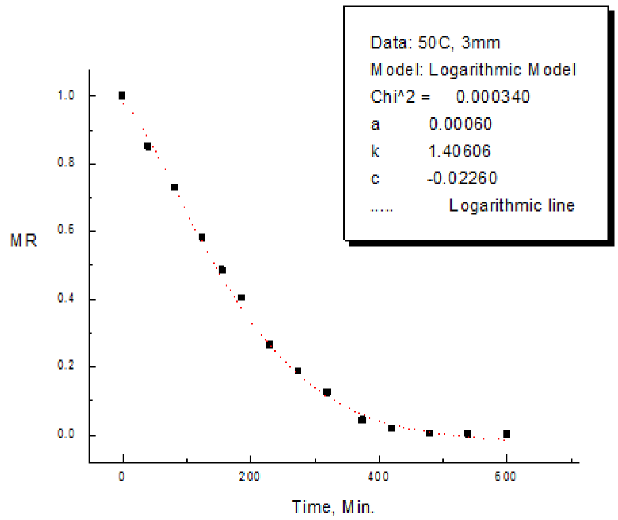

Figure 5: Variation in Moisture Ratio with drying time (50 °C, 3 mm thickness).

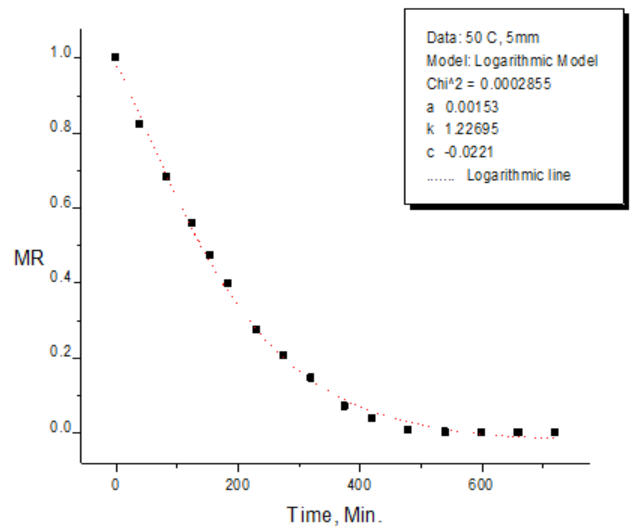

Figure 6: Variation in Moisture Ratio with drying time (50 °C, 5 mm thickness).

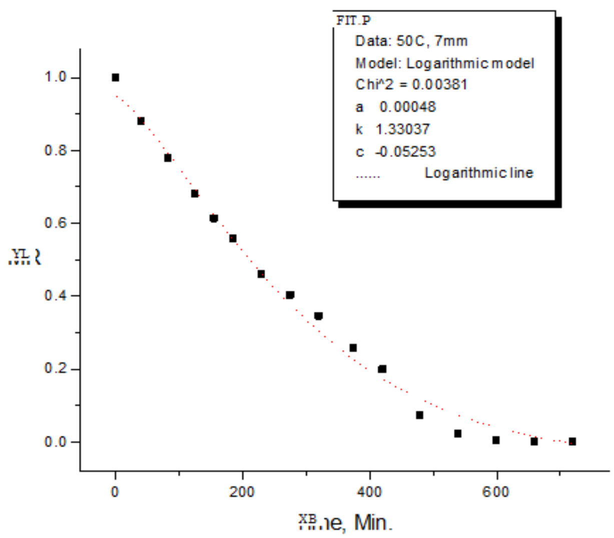

Figure 7: Variation in Moisture Ratio with drying time (50 °C, 7 mm thickness).

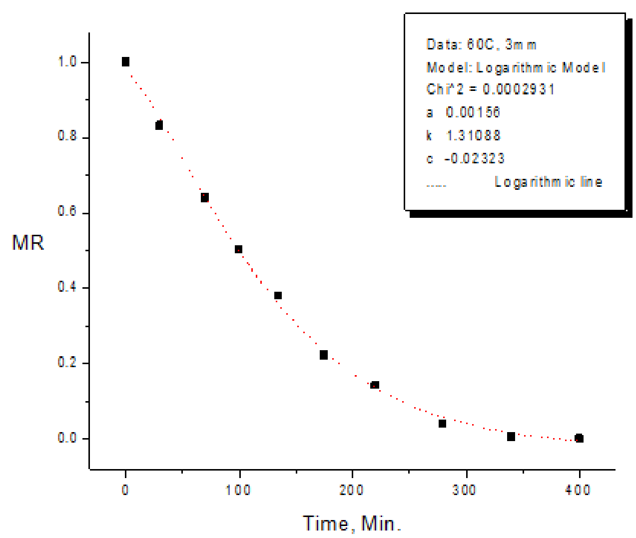

Figure 8: Variation in Moisture Ratio with drying time (60 °C, 3 mm thickness).

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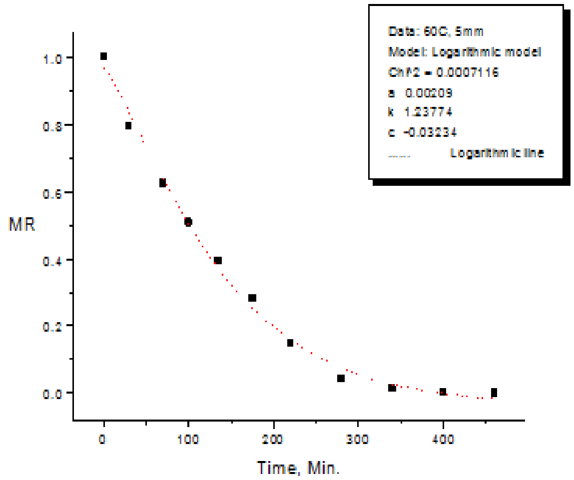

Figure 9: Variation in Moisture Ratio with drying time (60 °C, 5 mm thickness).

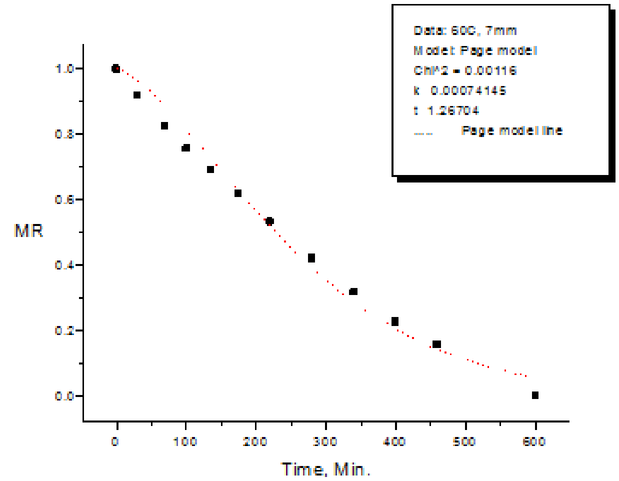

Figure 10: Variation in Moisture Ratio with drying time (60 °C, 7 mm thickness).

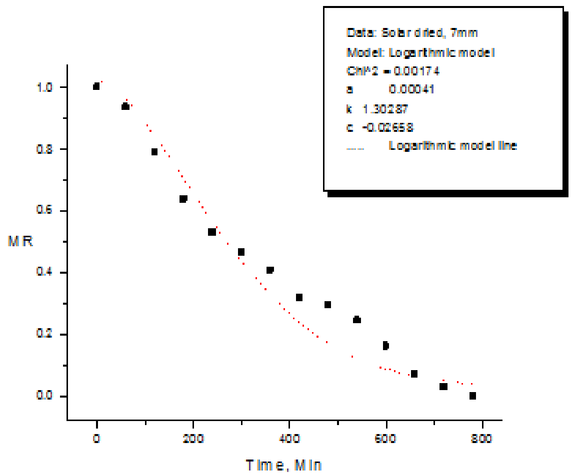

Figure 11: Variation in Moisture Ratio with time (Solar dried, 7mm thickness).

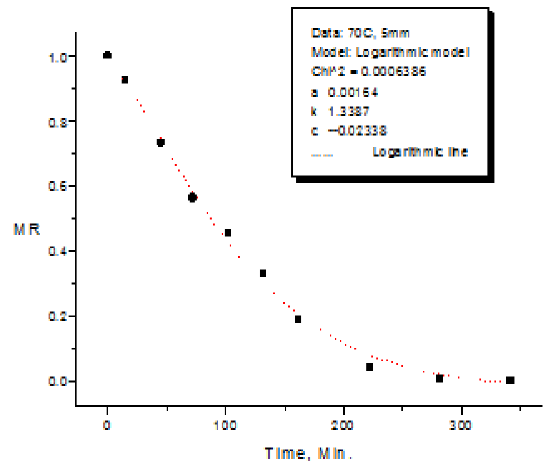

Figure 12: Variation in Moisture Ratio with drying time (70 °C, 5 mm thickness).

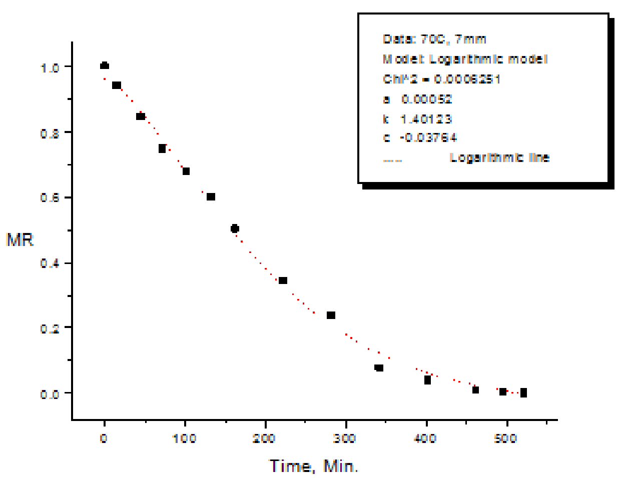

Figure 13: Variation in Moisture Ratio with drying time (70 °C, 7 mm thickness).

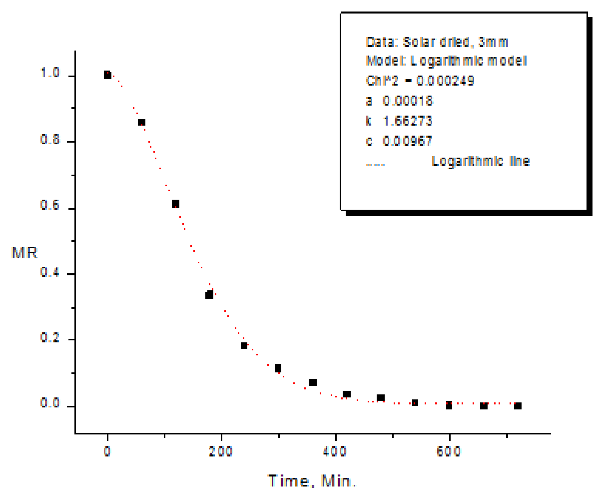

Figure 14: Variation in Moisture Ratio with drying time (70 °C, 7 mm thickness).

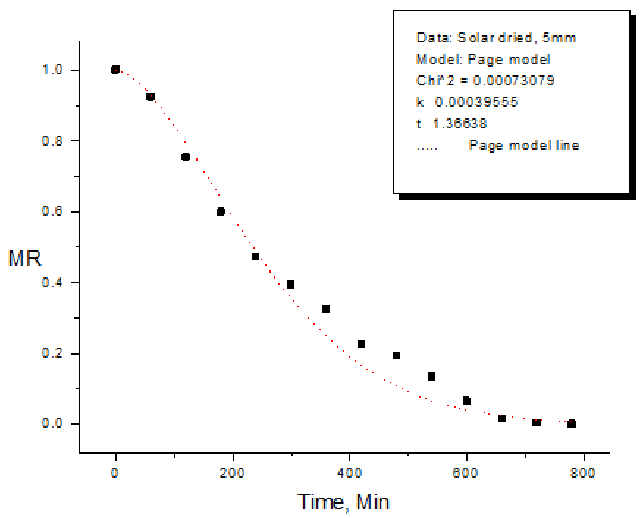

Figure 15: Variation in Moisture Ratio with time (Solar dried, 5mm thickness).

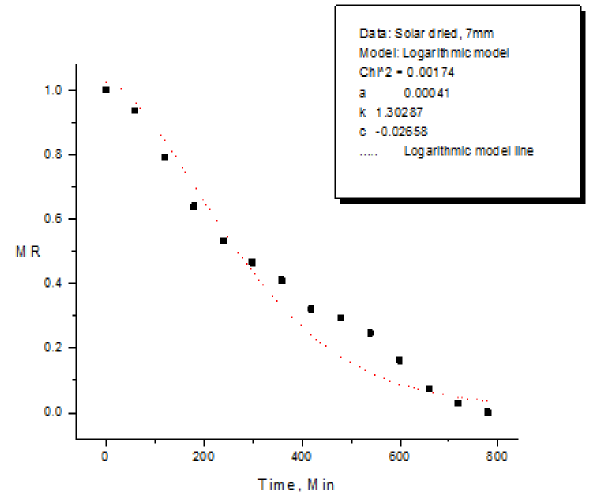

Figure 16: Variation in Moisture Ratio with time (Solar dried, 7mm thickness).

Conclusions

During the initial hours of drying, the drying rate was higher and diminishing with the time of drying. For all the drying runs carried out at different drying temperatures and thicknesses including solar drying, the falling rate drying phenomena was observed. For all the drying treatments taken the value of drying constants a, k and c under Logarithmic Model was varying from 0.00018 to 0.00233, 1.17 to 1.66 and -0.05244 to 0.01749 respectively.The minimum average drying rate of 3.36 g/hr was observed during 50 °C with 3 mm thickness drying run, while the maximum average drying rate as 5.66 g/hr at 70 °C with 5 mm thickness. As due to less amount of flesh present in 3mm thickness slice and lower temperature (50 °C), resulted into minimum depletion of moisture, reflecting minimum average drying rate. While drying at higher temperature with more thickness, induced rapid rate of evaporation, giving, maximum average drying rate at 70 °C with 5 mm thickness.

During 50 and 60 °C drying treatment the drying rate (g/g DM-h) for 5 mm thickness slice sample was found maximum followed by 3 and 7 mm. While for 70 °C and solar drying treatment the drying rate (g/g DM-h) of 3 mm slice sample was observed maximum followed by 5 and 7 mm. obviously, at higher thickness and less temperature, lesser would be the evaporation rate, results the lowest drying rate. But the results in terms of drying rate for 7 mm thickness for all the drying treatments are slightly deviated. This might due to considerable amount of stones present in the flesh of Kothimbda fruit. The slices were made with the skin as well as stones. Therefore, at higher thickness, more would be the number of stones and the skin surface area which diminished the evaporation, resulting into lesser drying rate.

The observations taken during all the drying treatments were fitted to Henderson and Pabis, Page and Logarithmic model. The values of coefficient of determination (r2) for all the three models under all the treatments were found to be above 0.9, suggesting good fit of the observations. Though, the value of r2 under the Logarithmic Model was more followed by page and Henderson and Pabis, indicating the Logarithmic model more reliable for prediction and found best fitted.

Nomenclature

a, c, k, n Constant for different drying model
g.water/g d.m. Gram Water per Gram Dry Matter
MR Moisture ratio
r2 Regression Co-efficient
RMSE Root Mean Square Error
χ2 Chi Square

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