Drying Kinetics and Colour Change of Mango Slices as Affected by Drying Temperature and Time

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Abstract. Thin-layer drying behaviour of mango slices (var. Kent) was investigated in a laboratory scale dryer, using heated ambient air temperatures of 60, 70 and 80°C at a constant air velocity of 1.5m/s and 3mm slice thickness. Besides the effects of drying air temperature on the drying characteristics, drying time and quality of dried products were determined. Drying curves obtained from the experimental data were then fitted to three well-known semi-empirical thin-layer drying models (Lewis model, Page model and Henderson & Pabis model). Model constants and coefficients were determined by nonlinear regression method. All the models were compared according to statistical parameters. Among the drying models investigated, the Page model satisfactory described the drying behaviour of mango slices. The effective moisture diffusivity varied from $4.97x10^{-10}$ to$10.83x\ 10^{-10}\ m^2/s$. Results indicated that drying took place in the falling rate period. The results have shown that, increasing air temperature causes shorter drying times. The combined effect of drying temperature and time on colour and re-hydration ratio were also evaluated. The colour was measured from the surface and expressed in the Hunter L*a*b* system. Moreover, the total colour change (ΔE), chroma (colour saturation), hue angle and browning index (BI) were determined. L* and b* parameters were found to decrease as affected by drying temperature and drying time, whereas a* parameter increases. Results also indicated that drying time has significant effect on colour change and rehydration ratio. The lowest total colour change and highest rehydration ratio were obtained at drying air temperature of 80C then 70 and finally 60C with drying time of 3,5 and 7 hours, respectively. In contrast to common practice, drying at elevated air temperature (80°C), instead of 60°C for a longer time, was optimal, since significant colour changes of mango slices were not observed. Moreover, at increased temperature, drying time was considerably shortened from about 7 h to 3h, resulting in significant extension of drying capacity.

Keywords: Colour change, drying models, mango slices, re-hydration ratio, thin-layer drying

Introduction

Mango (*Mangifera indica* L.) is one of the tropical and subtropical fruit of great importance for both economical and nutritional point of view. It is considered to be a good source of carbohydrates, vitamin C and very rich source of pro-vitamin A. In spite of its excellence, the perishable nature of this fruit and its short harvest season severely limit utilization. Drying may be an interesting method in order to prevent fresh fruit deterioration.

Drying is one of the most widely used primary methods of food preservation. The objective drying is the removal of water to the level at which microbial spoilage and deterioration reactions are greatly minimized (Akpinar and Bicer, 2004). It also provides longer shelf-life, smaller space for storage and lighter weight for transportation (Ertekin and Yaldiz, 2004). Sun drying is the most common method used to preserve agricultural products in tropical and subtropical countries. However, being unprotected from rain, wind-borne dirt and dust, infestation by insects, rodents and other animal, products may be seriously degraded to the extent that sometimes become inedible and the resulted loss of food quality in the dried products may have adverse economic effects on domestics and international markets. Therefore, the drying process of agricultural products should be undertaken in closed equipment (solar or industrial dryer) to improve the quality of the final product. The re-hydration capacity and colour characteristics were considered as the most important quality parameters for the dehydrated products. The re-hydration capacity is used to express ability of the dried material to absorb water.

The first quality judgment made by a consumer on a food at the point of sale is its visual appearance. Appearance analyses of foods are used in maintenance of food quality throughout and at the end of processing. Colour is one of the most important appearance attribute of food materials, since it influences consumer acceptability. Abnormal colours, especially those associated with deterioration in eating quality or with spoilage, cause the product to be rejected by the consumer (Avila and Silva, 1999). Therefore, the objectives of this study were:

1-To investigate the drying kinetics of mango fruit

2- To evaluate a suitable drying model for describing the drying process of mango fruit.

3- To determine the optimum drying temperature of mango fruit

4-To investigate the combined effect of drying temperature and time on colour change and re-hydration ratio

Materials and Methods

Raw Material

Fresh mangoes, var. "Kent", from Mali, were purchased at the wholesale market in Goettingen, Germany. The mangoes were left for 5days for post harvest ripening at 25±2ºC and 50% relative humidity (Pott et al, 2005). Fresh fruits were washed, manually peeled using stainless steel knife and sliced using an electric food-slicer (Krups variotronic, Germany) at 3 mm thickness.

Drying experiments

Drying experiments were performed in a laboratory cross flow dryer, Heraeus (Schütt, UT 6120 type, Germany). This is consisted of heating unit, temperature control unit, drying chamber and centrifugal fan of constant air velocity of 1.5 m/s. The average initial moisture content of the mango fruit was 82.5±0.4 % (w.b.), as determined by convective air drying at 135°C for 2h (AOAC, 2000)

Prior to starting the experiments, the dryer was run idle for about half an hour to reach thermal stabilization. Then the samples were uniformly spread within the tray as single layer of 3mm thickness. A representative sample of sliced mango for moisture loss assessment was placed in circular wire mesh of 10cm diameter and placed on to the centre of the tray. For measuring the mass of sample at any time during experimentation, sample on circular wire mesh was taken out of drying chamber and weighed on the digital balance and placed back into the drying chamber every 30 min during drying. The digital top pan balance 600±0.001g, (Sartorius, Goettingen, Germany) was kept near to the drying unit and weight measurement process took less than 10 seconds time. The drying process was stopped when the moisture content decreases to about 9±0.2 % (w.b). All the experiments were replicated two times at each air temperature and the average values were used for calculation.

Table.1.Slected drying models for describing mango slices drying data

Model name	Equation	References
Newton	MR= exp (-kt)	Lewis (1921
Henderson and Pabis	MR= a exp (-kt)	Henderson and Pabis (1961
Page	MR= exp ($-kt^n$)	Page (1949)

Non-linear regression analysis was used to evaluate the parameters of the selected models. The goodness of fit was determined using the four statistical parameters, i.e. coefficient of determination (R^2), the sum square error (SSE), The reduced chi-square (χ^2) and root mean square error (RMES). These parameters can be described in the following equations:

$$(SSE) = 1/N \Sigma^{N}_{i=1} (MR_{exp,i} - MR_{pred,i})^2 \quad (1)$$

$$(\chi 2) = \frac{\Sigma^{N}_{i=1} (MR_{exp,i} - MR_{pred,i})^2}{N-n} \quad (2)$$

$$(RMSE) = (1/N \Sigma^{N}_{i=1} (MR_{exp,i} - MR_{pred,i})^2)^{1/2} \quad (3)$$

Where:
exp. = Experimental data
pred. = Predicted data
N = Number of observations
n = Number of constants

Colour measurements

Colour parameters were measured with a Minolta CR-310 Chroma-meter (Minolta, Japan). The chroma meter consists of the respective measuring head and the data processor. The measuring head of the chroma meter CR-310 uses wide-area illumination and a 0° viewing angle and has 50 mm-diameter measuring area to average the reading. Hunter scale (L*, a*, b*) system was used. The Chroma meter was calibrated with a white standard tile with illuminant D_{65}(Y=94.3, x= .3156 and y= .3324) equivalent to HL system: HL = 97.10, a = -0.17 and b= 1.80. Calibration was made at each experiment. The parameter L* represents the brightness of the colour, a* the hue range of the colours red (+) and green (-) and b*hue range of colours yellow (+) and blue (-). Three measurements were made on the surface of sliced mango fresh and after drying and average values were made for calculation and each experiment was duplicated. From the colour values, total colour change (ΔE), chroma (C), hue angle (h) and browning index (BI) were calculated using equations described by Maskan (2001):

$$\Delta E = ((L_0-L)^2 + (a_0 - a)^2 + (b_0 - b)^2)^{1/2} \quad (4)$$

$$Chroma = (a^2 + b^2)^{1/2} \quad (5)$$

$$Hue\ angle = \tan^{-1}(b/a) \quad (6)$$

Where; subscript "0" refers to the colour reading of fresh mango slices. Fresh mango was used as a reference and a larger ΔE denotes greater colour change from the reference material (Maskan, 2001).

$$BI = [100(x-0.31)] / 0.17 \quad (7)$$

Where:

$$x = (a + 1.75L)/ (5.645L + a -3.012b)$$

Re-hydration ratio (Reconstitution ratio)

Re-hydration ratio was determined according to the official method of AOAC (1984), 5g of dried sample was soaked for 30 and 60 minutes in 50 ml distilled water, filtered through filter paper and then the filtrates were weighed.

Re-hydration ratio (R/R) = W_2/W_1 (8)

Where: W_2 = weight of drained material, g

W_1 = weight of dried material, g

Results and discussion

Drying characteristics

The effect of three temperatures on the drying curves of mango slices are shown in Fig. 1. it can be observed that there is no constant rate drying period in the drying of mango slices, and all the drying process occurred in the falling rate period. This indicates that diffusion is the dominant physical mechanisms governing moisture movement in the samples. These results are in agreement with Goyal et al (2006) for mango fruit.

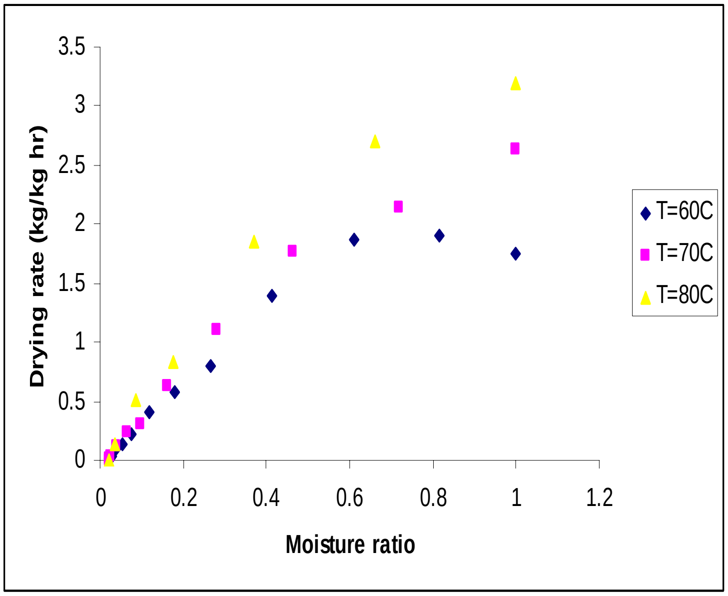

Fig. 1. Effect of drying air temperature and moisture ratio on the drying rate of mango slices.

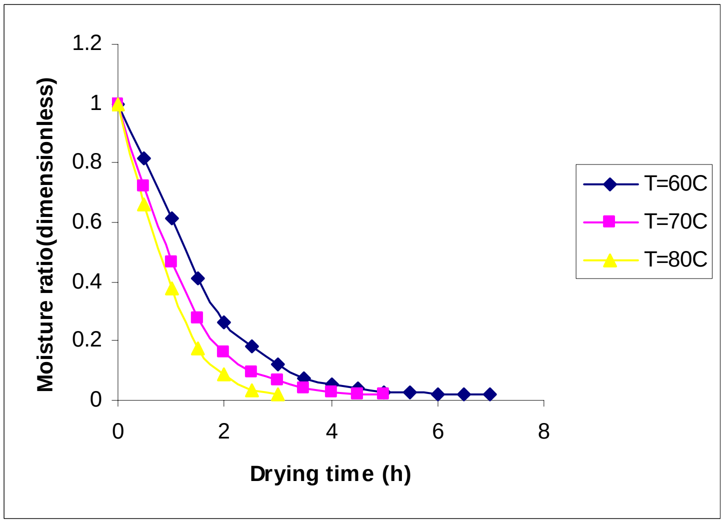

Fig. 2. Effect of drying air temperature and drying time on the moisture ratio of mango slices.

Combined effect of drying temperature and time on product colour

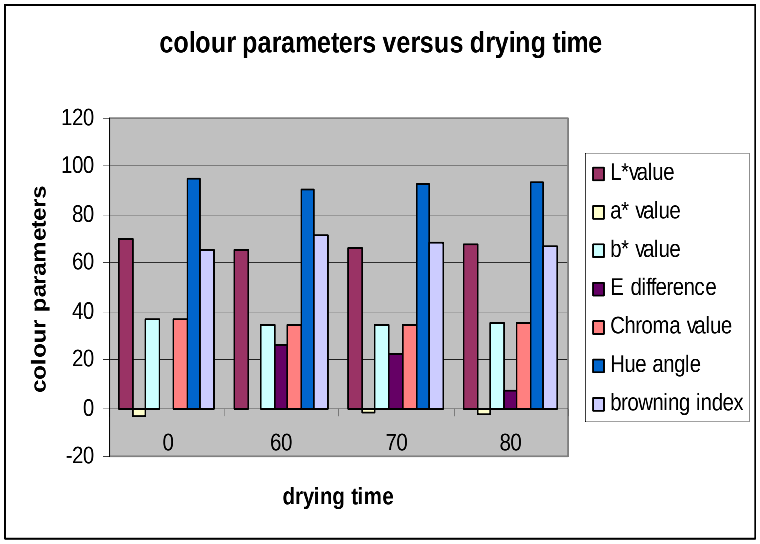

Fig.3. Colour parameters versus drying temperature

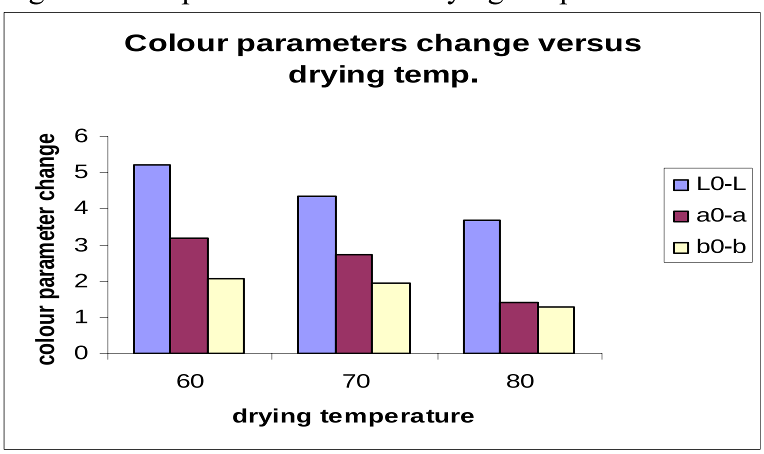

Fig.4. Colour parameters changes versus drying temperature

Re-hydration ratio of dried mango slices

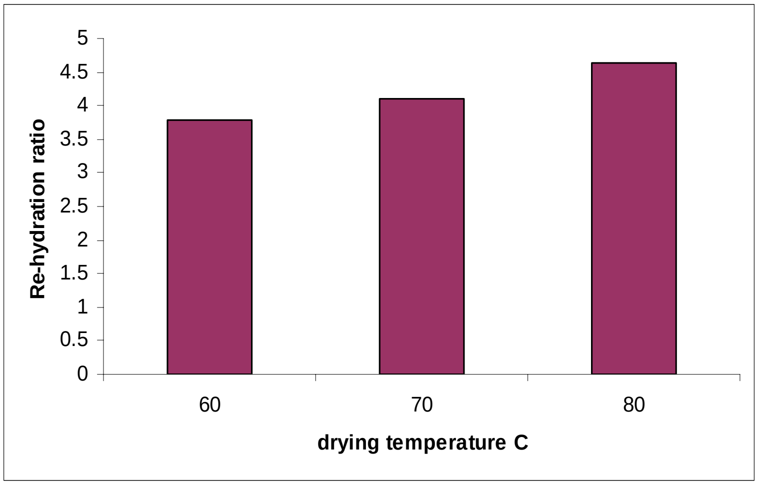

Fig.5. Combined effect of drying temperature and time on rehydration ratio of mango slices

Conclusions

The following conclusions can be drawn from this study**: -**

1- All the drying process of mango slices occurs in falling rate drying period.
2- The optimum drying temperature of mango slices is found to be 80ºC.
3- Drying time has significant effect on colour change of mango fruit
4- Page model was found to predict thin-layer drying characteristics of mango fruit well.

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