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Thin-Layer Drying of One Date Variety (Khalas)

Ali M. S. Al-Amri
Department of Agricultural Engineering,
College of Agricultural and Food Sciences, King Faisal University
Al-Ahsa, Saudi Arabia.

Abstract. A review of the literature on drying of agricultural products revealed that, very little efforts appear to have been done to measure the drying rates of dates under heated air conditions. In the present work, thin-layer drying studies were conducted in a laboratory dryer. Drying curves for one date variety were obtained for three dry bulb temperatures (37, 49 and 61ºC). A thin-layer drying equation has been applied and was found to describe the drying characteristics of the date variety under consideration reasonably well.

Introduction

Saudi Arabia is considered to be one of the leading date producing countries in the world with its annual production exceeding 500000 metric tons (Ministry of Agriculture, 1995). Thus dates play an important economic role for many farmers in the region. However, less than 10% of the dates produced are processed and considered for export, and as a result substantial amounts are annually lost.

Dates harvested in the Eastern Region are characterized by having a high initial moisture content which is undesirable as it contributes to the high spoilage rate experienced in this region. Farmers used to dry dates traditionally by spreading them on mats and leaving them to dry naturally. Such practices are poor as contamination by dust, dirt and insects is unavoidable. It is therefore envisaged that the design of a simple artificial solar dryer could contribute greatly in solving this problem. Nevertheless, before embarking on such a task basic data on the drying curves of dates are required. The objective of the present study is to develop a thin-layer drying model for one variety of Saudi dates cultivated in this region.

Literature Review

Efforts to measure drying rates of any date variety have not been reported in the literature. On the other hand, a remarkable amount of work on thin-layer drying of many agricultural products has been conducted. As a result, numerous mathematical models have been proposed by many researchers. Most of these studies have been carried out on thin-layer drying of grains, peanuts, seeds and some vegetables, but very little information is available on the drying of dates. These models included those of Lewis (1921), Page (1949), Whitaker and Young (1972), White *et al.* (1973), Syarief *et al.* (1984), Hummeida and El-Sheikh (1989) and Hansen *et al.* (1993).

Thin-layer drying models are formulated essentially to be used in the development of bulk drying simulation studies. A comprehensive review of such models has been given by Parry (1985). Thin-layer drying equations are divided into three groups, namely empirical equations, semi-empirical equations and theoretical equations (Parti, 1993). Empirical equations are not entertained because they neglect the internal resistance to mass transfer. On the other hand, theoretical equations were found to give inexact results in the first and last stages of drying because they tend to ignore the temperature change and moisture content dependence of the diffusion coefficient. However, the semi-empirical equations have been successfully applied by many researchers to describe drying rates for various crops.

The Lewis (1921) equation is considered one of the best semi-empirical drying equations and is expressed as:

$$MR = \frac{M - M_e}{M_o - M_e} = e^{-kt} \tag{1}$$

A modified version of the above equation, based on heat and mass transfer, was proposed by Hansen *et al.* (1993) and was expressed as:

$$MR = \sum_{i=1}^{j} A_i e^{-K_i t} \tag{2}$$

Where j takes values between 1 and ∞.

For the case of $j = 1$, K is known as the drying constant and is evaluated from thin-layer drying curves by plotting on semilog paper. Most K values are reported as a function of temperature only (Syarief *et al.*, 1984, Huizhen and Morey (1984)).

Experimental Setup

The thin-layer drying apparatus and instrumentation used in this study are shown schematically in (Fig. 1). The apparatus consisted of an air conditioning laboratory unit (P.A. Hilton model A573) which delivered controlled dry-bulb temperature and relative humidity air. The centrifugal fan of the unit is driven by a variable speed electric motor. Series of heating coils were fixed round the inner walls of the heating chamber just prior to the test chamber. Each heater was controlled by a separate switch.

The instruments used included wet-and dry-bulb thermometers to measure the relative humidity of the air. Other thermometers were used to sense the temperature of the entry and exit air. The air flow was measured with a differential head meter which consisted of an orifice plate and an inclined manometer.

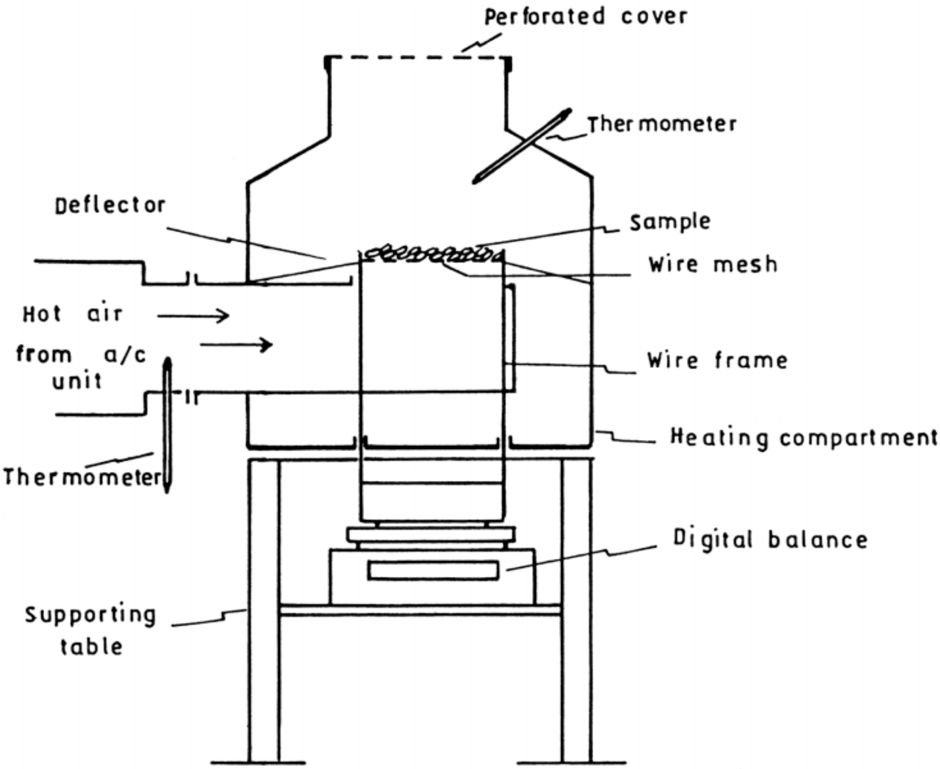

FIG. 1. Dates drying experimental setup.

The test chamber was an insulated metallic box of 40 cm × 40 cm cross section, 40 cm height with a 15 cm diameter horizontal opening connecting it to the plenum chamber. The chamber was insulated on all sides to reduce temperature variations from the surrounding. A circular opening of 27 cm diameter with a perforated lid was provided at the top of the test chamber which allowed insertion and removal of the sample. The tray carrying the sample was held inside the test chamber on a 4-leg 3 mm diameter copper rod frame, where each leg was allowed to pass through a small hole drilled in the bottom of the chamber, so as to allow them to rest on a digital balance placed underneath. The sample tray, 18 cm × 22 cm, was framed from a 3 mm diameter copper rod with its sides and bottom wrapped with a 5 mm wire mesh.

Test Procedure

One date variety (Khalas), considered for the thin-layer drying tests, was obtained from a farm in Al-Ahsa in the Eastern Province of Saudi Arabia. Dates were hand-picked during harvest season (1997) and were put in plastic containers, each weighing approximately 200 g and were stored in the laboratory.

Before each test run, the drying system was allowed to stabilize at the desired air condition prior to the start of the test. With the fan off, the 200 g sample was placed in the drying tray to determine its initial weight. Then the fan was turned on to start the test. At the same time a sample of about 50 g was set aside to determine its moisture content by placing it in an oven set at 103ºC for 24 hours.

Drying continued for some time until, no change in weight of samples was observed, where at this stage, the sample was assumed to be in equilibrium with the drying environment. Three test runs at three dry-bulb temperatures (37, 49, 61ºC) were carried out to obtain drying profiles of dates. The dry bulb temperature and relative humidity inside the dying chamber were frequently monitored with a digital hygrometer. Each test condition was replicated two times.

The start of each drying test was recorded using a digital watch. The ambient temperature and relative humidity were also noted. Each sample was dried for a certain period of time, during which periodic weighings every 20 minutes were made. To avoid the effect of the air lift on the drying tray, weighing of the sample was conducted while the fan was switched off. This procedure did not take more than 10 seconds. When a constant weight was obtained for three consecutive readings, it was concluded that the sample has reached equilibrium conditions and the test was terminated.

Results and Discussion

The collected data were analysed to study the drying of dates under heated air conditions. In order to compare thin-layer drying rates for the three drying temperatures under consideration, moisture ratios as a function of time in hours are plotted in (Fig. 2). The results show that drying time decrease as drying temperature increase.

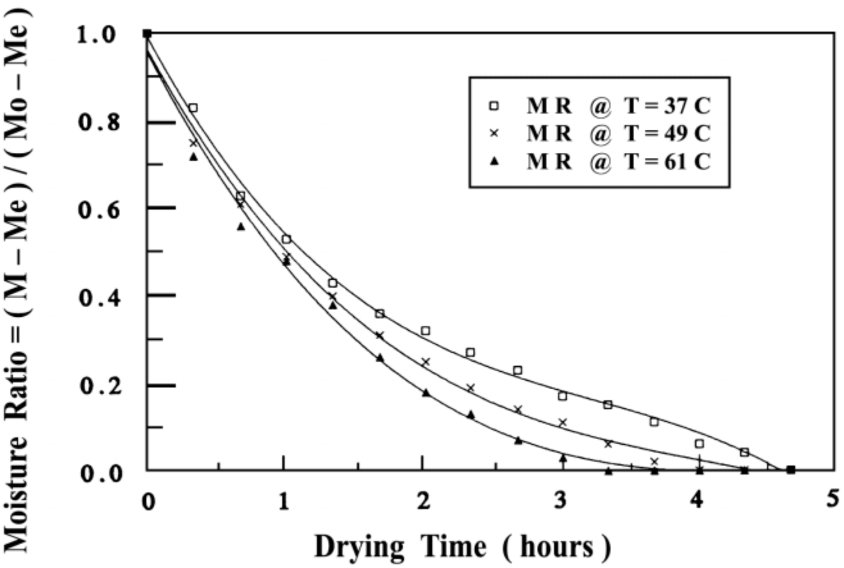

FIG. 2. Drying curves for Khalas Dates versus drying temperature.

The model used to fit the experimental data is of the following form:

$$MR = \frac{M - M_e}{M_o - M_e} = A \exp(-Kt) \tag{3}$$

Where MR = moisture ratio
M = moisture content, % dry basis (d.b)
M_o = initial moisture content, % d.b.
M_e = equilibrium moisture content, % d.b.
K = drying constant, h^{-1}
A = constant
t = time, h

A procedure described by Hall (1980) for determining the drying constant K is used in this analysis. A semilogarithmic plot of moisture ratio (MR) versus time (t) is shown in (Fig. 3) for the same results shown in (Fig. 2), except that the curves are truncated for $MR < 0.1$. The data show almost straight line relationships. Table 1 shows results of a regression analysis where parameters of equation 3 are tabulated for each of the drying temperatures tested.

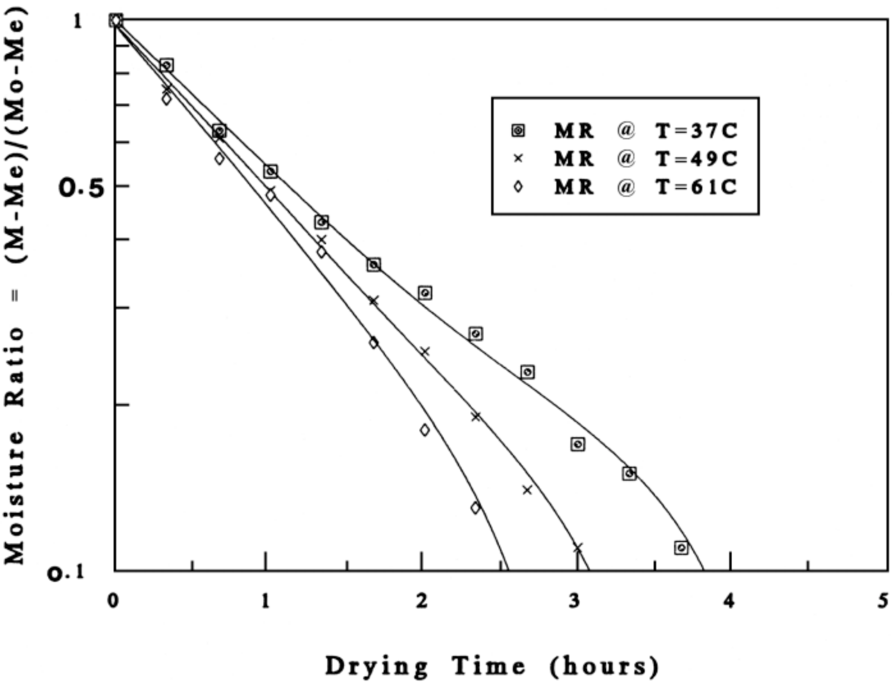

FIG. 3. Semilogarithmic plot of drying curves for Khalas Dates as a function of drying temperature.

Several equations were tested in the regression procedure to express A. The equation that provided best results is of the form:

$$A = -42.57 + 26.66 \times 10^{-2}\, T - 40.55 \times 10^{-5}\, T^2 \tag{4}$$

with a coefficient of determination (R^2) of 0.9

Where T = temperature, °K.

TABLE 1. Evaluation of thin-layer drying constants for (Khalas) dates ($MR = A\ e^{-kt}$)

Dry bulb temp. ºC	Relative humidity %	No. of observations	A	K(h^{-1})	R^2 value
37	23.0	15	1.088	0.665	0.960
49	20.5	13	1.222	0.907	0.927
61	16.5	11	1.223	1.063	0.948

A regression analysis of the drying constant K versus drying temperature in °K gave:

$$K = -33.41 + 0.19T - 2.80 \times 10^{-4}\ T^2 \qquad (5)$$

with a coefficient of determination (R^2) of 0.998.

The proposed model for predicting thin-layer drying rates of dates is based on equation (3) with the constant "A" predicted by equation (4) and the drying constant "K" predicted using equation (5). The model was checked by plotting the predicted moisture ratio against the observed moisture ratio for all test conditions as shown in (Fig. 4). This figure shows close agreement between the predicted and observed moisture ratios as most of the points are shown to fall very close to the line ($y = x$). These results indicate that the proposed model is suitable for predicting most moisture ratios within reasonable range throughout the entire period of each test condition.

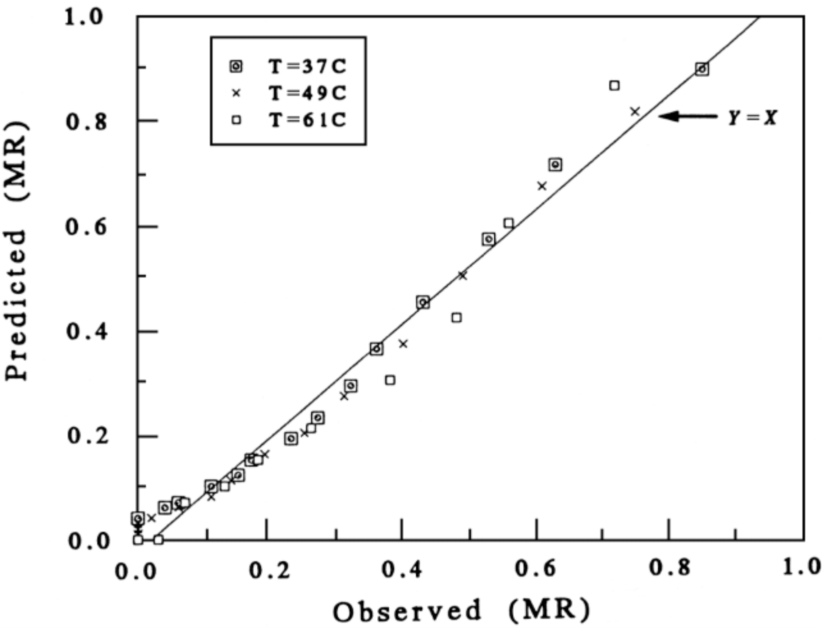

FIG. 4. Comparison between the predicted MR against the observed MR.

Conclusion

A comprehensive literature review on drying of agricultural products revealed that information on dates drying is scarce. In the present work thin-layer drying data have been collected for one date variety (Khalas) grown in the Eastern Province of Saudi Arabia. Experiments were conducted in a laboratory dryer at three dry bulb temperatures (37, 49 and 61ºC). Moisture ratios were calculated for each test condition and drying curves were obtained. Using these informations, a thin-layer drying model has been proposed.

Moisture ratios predicted with the proposed model were shown to be within reasonable agreement when compared to observed moisture ratios obtained from three actual test runs at different drying air temperatures. It is recommended that further studies should be conducted on other date varieties at wider experimental test conditions in order to arrive at a more generalized and comprehensive model.

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تجفيـف نوع (الخـلاص) من التمـور في طبقـة رقيقـــة

علي مفرح صالح العمري

قسم الهندسة الزراعية ، كلية العلوم الزراعية والأغذية ، جامعة الملك فيصل الأحســـــاء - المملكة العربية السعودية

المستخلص . عند مراجعة كثير من الدراسات والبحوث التي تتعلق بموضوع تجفيف مختلف المنتجات الزراعية تبين أنه لم تبذل مجهودات كافية للقيام بقياس معدلات تجفيف التمور عند تعريضها للهواء الساخن المدفوع .

وفي هذا البحث تمت دراسة تجفيف نوع واحد من التمور (من نوع تمر الخلاص) في مجفف معملي . وقد تم الحصول على منحنيات التجفيف عند درجات حرارة للهواء تراوحت بين ٣٧ْ - ٦١ْم . وبناءً على ذلك فقد تمّ الوصول إلى معادلة رياضية تربط معدلات التجفيف مع درجة الحرارة لنوع التمور تحت الدراسة بصورة مقبولة .