MODELING DRYING KINETICS OF DOMINGA GRAPES

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Keywords: drying kinetics, grapes, modeling

ABSTRACT

Air drying kinetics of grapes (Dominga variety) were determined at 30, 40 and 50ºC and velocities of 0.45 and 0.60 m/s, using a pilot tunnel tray drier. The air relative humidity ranged from 3 to 35%.

The characteristic drying curves presented a single falling-rate behavior. Several models were attempted to fit the drying data. The effect of temperature on grape drying kinetics was also quantified. Air velocity had no significant effect on drying rates, in the tested range. The exponential model presented the best fit, and a drying rate and equilibrium moisture content were obtained for each isothermal experiment. Temperature influence on drying rate followed an Arrhenius type behavior. A one-step non-linear regression to all the data allowed to obtain an activation energy of 31.8 ± 0.3 kJ/mol and a mean equilibrium moisture content of 0.338 ± 0.007 kg water/kg d.m.

The developed model is crucial for simulating drying times of Dominga grapes.

INTRODUCTION

Several authors have been studying grapes drying kinetics and in particular the effects of different experimental conditions (Mahmutõglu et al., 1996; Riva and Peri, 1986).

To fit experimental data several models have been used. The two-compartment diffusion model was developed by Glenn (Madamba et al., 1996):

$$\frac{M - Me}{Mo - Me} = A_o \exp(-k_o t) + A_1 \exp(-k_1 t) \tag{1}$$

Two simplified forms of Fick's diffusion equation have also been frequently used. The two following equations are an example for spherical products:

$$\frac{M - Me}{Mo - Me} = \frac{6}{\pi^2} \exp(\frac{-\pi^2 D t}{r^2}) \tag{2}$$

$$\frac{M}{Mo} = \frac{6}{\pi^2} \exp(\frac{-\pi^2 D t}{r^2}) \tag{3}$$

The Exponential model (Newman et al., 1996) as also been applied to food products:

$$\frac{M - Me}{Mo - Me} = \exp(-K t) \tag{4}$$

The effect of temperature on drying rate constant, K, is usually considered to have an Arrhenius behavior:

$$K = Ko \exp\left[-\frac{Ea}{R} (\frac{1}{T} - \frac{1}{To}) \right] \tag{5}$$

The drying of grapes is usually carried out in solar dryers. To simulate drying times for this type of product, the effect of variable conditions such as air temperature, velocity and humidity is required. Therefore, the objective of this work was to quantify the influence of air temperature and velocity on the drying kinetics of Dominga grapes.

MATERIALS AND METHODS

This study was carried out with a pilot plant tray drier (Armfield UOP8) with forced air and temperature controller. This equipment comprises an air duct mounted on a floor standing frame. Air is drawn into the duct by a motor driven axial flow fan impeller. Air temperature is controlled by a power regulator of the electrically heated element. Four trays placed in the central section of the duct are carried on a support frame that is attached to a digital balance Sartorius, model BP6100, allowing on-line acquisition of total weight. This was carried out every 5 minutes.

Upstream and downstream of the drying trays two air humidity probes and two thermocouples are placed. A Grant Squirrel meter datalogger acquires on-line, a mean value of 10 s measures, every 5 minutes.

Grapes (Dominga variety) obtained from the Porto supplier market were used in these experiments, and were stored at 4ºC and 80% RH. Samples were prepared, selecting grapes without wounds from different branches and removing peduncles. Grapes were blanched in hot water at 100ºC during 30s, after being slightly washed in cold water. Initial water content of blanched grapes was determined in triplicate, by drying the samples in an oven at 70ºC, until a stable weight value was reached.

Approximately 300g of grapes were placed close to each other, in the tray drier, in 3 rows and the weight acquisition started, with monitored temperature and relative humidity. Regular air velocity measures were made with a vane anemometer (Airflow LCA 6000).

Drying experiments were carried out at 30, 40 and 50ºC, and 0.45 and 0.60 m/s air velocity.

RESULTS AND DISCUSSION

Experimental data was transformed to drying curves, in the form of water content on a dry basis (kg water content / kg dry mater) versus drying time. Figures 1 and 2 present the effect of different air velocities and air temperatures, respectively, on drying kinetics. A single falling-rate behavior was observed in the characteristic drying curves and the exponential model ‘equation (4)’ presented the best fit to data. Table 1 presents the parameters values for each experiment.

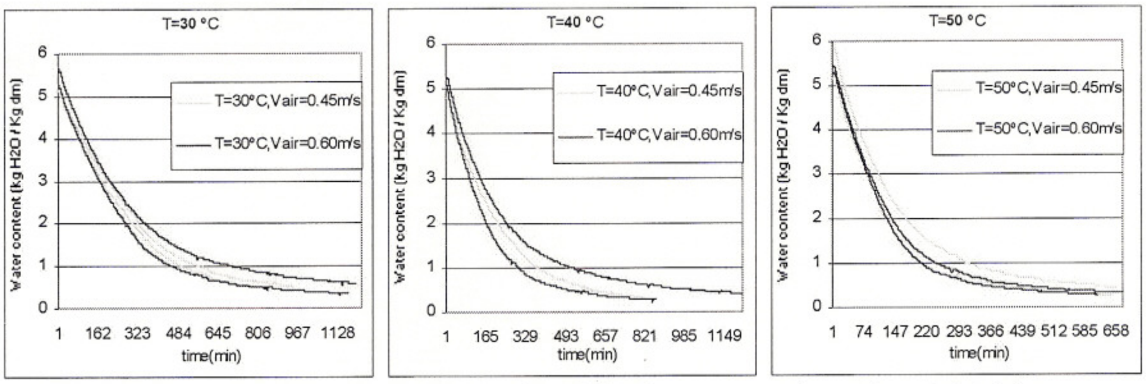

Figure 1. Effect of air velocity on drying kinetics of Dominga grapes (experimental data).

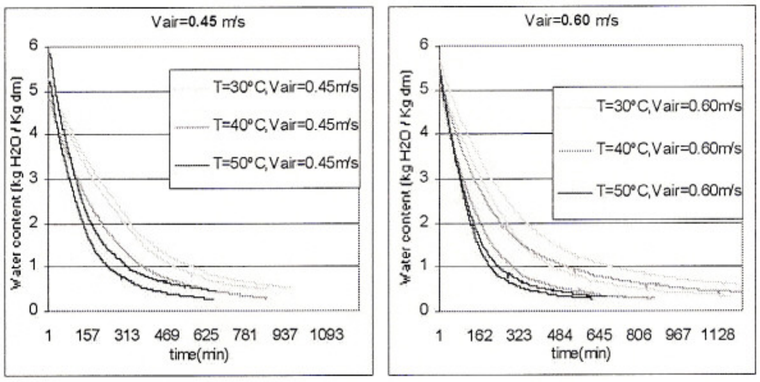

Figure 2. Effect of air temperature on drying kinetics of Dominga grapes.

Table 1. Model parameters and corresponding experiments.

Experiment no.	*T (ºC)*	V_{air} *(m/s)*	*K* (min^{-1})	*Me (kg/kg dm)*	r^2
1	30	0.45	0.0006563	0.0939	0.9993
2	50	0.45	0.001413	0.4201	0.9995
3	40	0.45	0.0008827	0.1736	0.9997
4	30	0.45	0.0006237	0.1762	0.9992
5	50	0.45	0.001479	0.2226	0.9987
6	30	0.60	0.000778	0.2613	0.9984
7	50	0.60	0.001663	0.2174	0.9968
8	40	0.60	0.001227	0.2613	0.9993
9	50	0.60	0.001573	0.2970	0.9985
10	30	0.60	0.0007049	0.5398	0.9999
11	40	0.60	0.0008954	0.4690	0.9994

A significant difference between the drying rates for the two air velocities was not observed. From the model parameters it was concluded that air velocity, in the tested range, has no significant effect. This result agrees with the fact that drying occurred in the falling-rate period. During this period internal diffusion is the main mechanism, therefore air velocity has little effect on drying rate (Karathanos and Belessiotis, 1997).

On the other hand, it is clear that drying rate increases significantly with air temperature. This effect was well described by the Arrhenius law 'equation (5)'.

A one-step non-linear regression performed simultaneously to all the data (Arabshahi and Lund, 1985) allowed to obtain an activation energy of 31.8 ± 0.3 kJ/mol and a mean equilibrium moisture content of 0.338 ± 0.007 kg water/kg d.m..

The developed model can be used as a tool to simulate drying times of Dominga grapes, under variable temperature and air velocity conditions (in the range of values used for model development).

ACKNOWLEDGMENT

The author Inês N. Ramos would like to thank PRAXIS XXI PhD grant to Fundação para a Ciência e a Tecnologia, Portugal. The authors also acknowledge the Ministério da Agricultura, do Desenvolvimento Rural e das Pescas, the financial support to the project PAMAF 2029.

NOTATION

A_o, A_1	parameters of the Glenn model	
D	moisture diffusion coefficient	m^2/min
Ea	activation energy	kJ/ kg
k_o, k_1	parameters of the Glenn model	min^{-1}
K	drying rate constant	min^{-1}
Ko	drying rate constant at reference temperature (To)	min^{-1}
M	moisture content	kg water/ kg dry mater
Me	equilibrium moisture content	kg water/ kg dry mater
Mo	initial moisture content	kg water/ kg dry mater
r	radius	m
R	universal gas constant	J/mol K
t	time	min
T	temperature	K
To	reference temperature	K

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