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DRYING KINETICS OF TWO GRAPE VARIETIES OF ITALY

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ABSTRACT

Two varieties of grapes, white grape and red grape grown in the Campania region of Italy were selected for the study of drying characteristics. Comparisons were made with treated and untreated grapes under constant drying condition of 50° C in a conventional drying system. This temperature was selected to represent farm drying conditions. Grapes were purchased from a local market from the same supplier to maintain the same size of grapes and same properties. An abrasive physical treatment was used as pretreatment. The drying curves were constructed and drying kinetics was calculated using several commonly available models. It was found that treated samples show better drying characteristics than untreated samples. The objective of this study is to obtain drying kinetics which can be used to optimize the drying operations in grape drying.

INTRODUCTION

Drying, which is the oldest of food preservation practiced by mankind, and is the most important process to preserve fruits and vegetables since has a great effect on the quality of the dried products. The major objective in drying products is the reduction of the moisture content to a level that allows safe storage over an extended period. In traditional drying method which includes spreading under sun, the drying time is long and the product is directly affected by external conditions. This drying method has a number of disadvantages, including dusting, microorganism reproduction, decaying, and dependency on local meteorological conditions, etc. In economic terms, it is faced with issues such as loss of quality and price of product. It is an obligation to apply modern technology and production methods to the drying processes in order to obtain hygienic and good-quality dried products.

Grape is one of the world's largest fruit crops and Italy is one of the countries which produce grapes in large quantities. Dried grapes is a source of carbohydrates and it contains large amounts of iron, vitamins A, B1, B2, B3, B6 and minerals and usually included in breakfast cereals, dairy, bakery and confectionery. In general, the fresh grapes are untreated/pre-treated and left for sun drying. Drying process usually takes 15–20 days for untreated grapes and 7–12 days for pretreated grapes, depending on the relative humidity and temperature of ambient air (Sansiribhan et al., 2012). To improve the quality of grapes, traditional drying techniques should be replaced with the industrial drying processes such as solar or hot air dryers. Hot air dryers deliver far more rapid drying, providing uniformity and hygiene to the products which are inevitable for industrial food drying processes (Doymaz, 2006). Grape drying to produce raisins is a very slow process, due to the peculiar structure of grape peel. Grapes are covered naturally with a thin-layer of wax; hence, it is necessary to increase water transport from grape berries during drying process. Peel removal has been carried out by using either chemical or physical pretreatments (Da Silva et al., 2012). As a consequence, the drying time of pretreated grapes is up to four times shorter than the drying time of untreated grapes. Physical pretreatment consisting of a preliminary abrasion of the grape peel so as to accelerate grape drying process.

Simulation models play an important role in the study of drying methods and their improvement. It is difficult to define the moisture transfer in food products in mathematical terms (Bingol et al, 2008). Some researchers have stated that food products usually dry in decreasing rate period and that the moisture transfer in solids can be explained by Fick's diffusion law (Clary et al., 2007). Thin-layer drying models can be divided into three categories, namely theoretical, semi-theoretical and experimental.

In this study, white grape and red grape were selected. Separate experiments were conducted using fresh samples and samples subjected to a physical pre-treatment used in drying. A laboratory conventional dryer was used for all drying experiments. The drying parameters of treated and untreated grape at 50°C were examined. The purpose of the present work is to investigate the effect of pre-treatment solutions on the drying rates of different grapes.

MATERIALS AND METHODS

Drying experimentation

Red and White grapes harvested from Campania region (Italy), were used throughout all experiments. The abrasion of the grape peel was carried out in a shaker, the walls of which were covered by coating with abrasive sheets (USM ± Canada, grit range 60±80) as reported before (Di Matteo et al., 2000). Drying experiments were carried out in a convection oven at 50°C, with an air speed of 2.3 m/s, so as to reduce the average moisture of grapes to about 10% w/w.

Mathematical Modeling

The data were analyzed by the analysis of variance (ANOVA) to evaluate differences and nonlinear regression to obtain suitable models. Model parameters were estimated separately for all replicates. The significance differences were examined by comparing parameters in equations fitted to the different replications. The final model was constructed using least square mean parameter values. Simplified drying models have been used to quantify drying kinetics of various agro food materials. Mathematical modeling was used to explain the drying behaviour of grape. Mass transfer mechanisms considered are moisture diffusion in the solid phase towards its external surface, followed by vaporization and convective moisture transfer to the drying stream.

Empirical Models

Empirical models that are commonly applied for vegetable food materials were adopted from the literature, as shown in Table 1. The empirical constants for the drying models were determined

experimentally from normalized drying curves at the drying temperature. Modeling was carried out using the least square method and the Microsoft Excel spreadsheet (Microsoft 2003) was used to perform this task using the SOLVER tool based on the Generalized Reduced gradient (GRG) method. The goodness of fit for each model was established using the nonlinear optimization method where the objective function is to minimize the sum of squares of residuals and thus perform least-square curve fitting. The goodness of fit for each model was evaluated based on statistical parameter coefficient of determination (R^2).

Table 1. Models used

Model name	Equation
Simple model	$MR = a \exp(-kt)$
Page Model	$MR = a \exp(-kt^n)$
Two compartment model	$MR = a_1 \exp(-k_1t) + a_2 \exp(-k_2t)$

RESULTS AND DISCUSSION

Drying kinetics

Figure 1 shows, drying kinetics for untreated white grapes and model using two compartment model. This graph shows an exponential trend and treated grape dried faster than untreated grapes. This is true for both white and red grapes. The behavior is similar to reported in the literature. The physical treatment given before drying may have contributed to the faster drying of treated grapes both for white and red varieties. The average moisture content was expressed as non-dimensional moisture ration 'MR' and used to plot drying curves with time in hours.

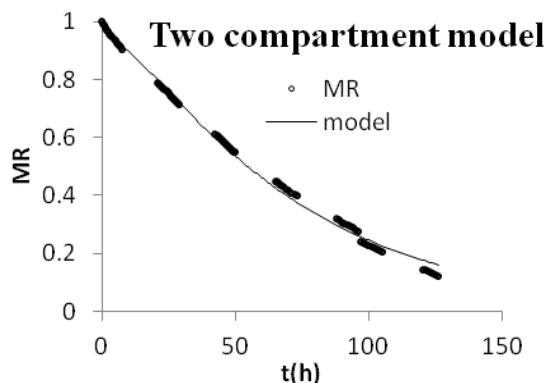


Figure 1. Drying behavior of untreated white grape, data and model.

Three commonly used mathematical models were taken to identify the most suitable model to describe the drying behavior. Mathematical modeling of the drying curves was conducted using nonlinear regression analysis coupled with generalized reduced gradient algorithm. All the model constants were calculated based on the iterative method and estimated parameters are given in Table 2.

From curves of moisture ratio versus drying time, for pre/untreated samples shown in Fig. 1, it is apparent that moisture ratio decreases continuously with drying time. In this curves, a constant-rate period was not observed in any of the experiments of this work, hence the entire drying process for treated/untreated grapes occurs in the range of the falling-rate period. This shows that diffusion is the dominant physical mechanism governing moisture movement in the samples. Similar results were obtained by different authors on drying of various fruits such as seedless grape and apricot

(Doymaz, 2006; Ramos et al., 2004). According to the results in Fig. 1, pre-treatment solution is very important parameter that affects the drying time.

Table 2. Estimated parameters of the drying models

Model		White grape (untreated)	White Grape (treated)	Red grape (untreated)	Red grape (treated)
Simple	a	1.02294	0.924101	1.02398	0.92815
	k	0.013364	0.043732	0.01293	0.06596
	R ²	0.9887	0.9945	0.9900	0.9906
Page	a	0.96846	0.99661	0.977279	1.04767
	k	0.004057	0.087733	0.00451	0.15189
	n	1.2662	0.810486	1.28852	0.7563
	R ²	0.9971	0.9991	0.9978	0.9974
Two compartment	a ₁	-0.29824	0.85567	-0.28411	0.3023
	k ₁	0.050894	0.0424	0.047605	0.02968
	a ₂	1.268278	0.1592	1.267642	0.7043
	k ₂	0.016364	0.475	0.015892	0.12969
	R ²	0.9958	0.9997	0.9974	0.9994

While examining the three models for moisture ratio values obtained according to experiment results, the attention was paid to find the model where coefficients of determination (R²) was the highest. When the results given in Table 2 are examined, it is seen that the highest correlation coefficient is represented by two compartment model for the treated white and red grapes and Page model for untreated white and red grapes.

CONCLUSION

The drying occurs at falling rate period for all the experiments. Treated grape showed reduced drying times due to faster release of moisture. This may be attributed to the lower resistance created by skin due to the treatment when diffusion of moisture through the skin occurs.

NOTATION

a	constant in models	
k	drying constant in models	h ⁻¹
MR	experimental moisture ratio	
n	constant, positive integer	
R ²	coefficient of determination	
t	drying time	h

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