SOLAR DRYING KINETICS OF PEARS HARVESTED AT DIFFERENT RIPENING STAGES

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Abstract: In Portugal, pears of the variety S. Bartolomeu have been used to produce a traditional product named "pêra passa de Viseu". These pears are dried at direct open air sun exposure, following a multi-step procedure. In the last years some investigation around this product and the production method has been carried out to better understand them and establish alternative production techniques. In the present work pears of the variety S. Bartolomeu, harvested at three different moments, corresponding to three ripening stages, were dried in a solar stove and their drying kinetics were studied. From the results obtained it was possible to conclude that all the six equations used to model the drying kinetics fit with accuracy the experimental data, and that the differences found in the three essays result mainly from the climatic conditions that occurred in each drying period.

Keywords: Drying kinetics, dried pear, solar drying, solar stove.

1. INTRODUCTION

Drying of agricultural products under direct sunlight is the traditional way of preserving many fruits and vegetables. Traditional sun drying involves either storing the product under direct sunlight or in indirect sunlight by putting it under transparent plastic films, glass or non-transparent covers [1].

The use of the sun to dry foods has the advantage of small or negligible installation and energy costs. However the running costs may be high due to intensive labor and slowness of the process. Moreover, several factors make solar drying less attractive, such as: climatic conditions, product pollution from dust or from animal contamination, other types of infestation and microbial and mould contamination in humid environments [1]. For this reason, the use of solar stoves is advantageous, making use of the sun as energy source without some disadvantages of the direct open-air exposure.

In Portugal, over the years, dried pears have been traditionally produced from pears of the variety S. Bartolomeu, harvested in late August. The traditional solar-drying method involved the direct sun exposure of the fruits, in a multi-step operation [2,3]. In the last years some investigation has been taking place in order to, on one way, better understand this product, it's characteristics and production methodology, and, on the other way, to propose alternative production processes conceived to achieve a product with good sanitary and organoleptic quality with better yields and lower costs.

In the present work pears of the variety S. Bartolomeu, harvested at three different moments, corresponding to three ripening stages, were dried in a solar stove and their drying kinetics was studied.

2. EXPERIMENTAL

The pears of the variety S. Bartolomeu were purchased to a farmer in Oliveira do Hospital, and they were harvested on the 27th of July, 10th of August and 20th of August, respectively for essays 1, 2 and 3. The pears were peeled and left to dry uncut inside a solar stove, over nylon nets. The temperature and relative humidity inside the stove were monitored every 10 minutes with a hygrometer Lufft-Opus 10. Three samples were removed from the stove everyday at 10:00 h, 14:00h and 18:00 h, to analyze their moisture content with a Halogen Moisture Analyser HG53 from Mettler Toledo.
The drying kinetics was monitored in terms of evolution of the moisture content along drying, and the data were then expressed in terms of the dimensionless variable moisture ratio, defined as:

$$MR = (W - W_e)/(W_0 - W_e)) \qquad (1)$$

where W is the dry basis moisture content at time t, W_0 is the initial moisture content and W_e is the equilibrium moisture content. To model the drying kinetics the experimental points (MR, t) were fit to different empirical kinetic models from literature, presented in Table 1.

Table 1 – Empirical models to describe the drying kinetics [4].

Model name	**Equation**
Newton	$MR = \exp(- k t)$
Henderson & Pabis	$MR = a \exp(- k t)$
Logarithmic	$MR = a \exp(- k t) + c$
Logarithmic two terms	$MR = a \exp(- k_0 t) + b \exp(- k_1 t)$
Wang & Singh	$MR = 1 + a t + b t^2$
Diffusional Aproach	$MR = a \exp(- k t) + (1 - a) \exp(- k b t)$

3. RESULTS AND DISCUSSION

In Figure 1 the conditions inside the stove (temperature and relative humidity) are shown for the three essays, together with the moisture of the pears. It is possible to verify that in essay 1 the drying was quite fast, with the pears reaching a moisture content of about 20 % in the 4th day. This high drying rate was a direct consequence of the very temperatures that occurred inside the stove in the first day, reaching the 60 ºC. The second essay was slower, and the moisture loss was less regular, since in this case the temperatures in the first three days were around 40 ºC, and the relative humidity is very high, approaching 100 %. Moreover, the fifth day was rainy, leading to very high relative humidities and low temperatures. Is Essay 3 until the 3rd day the moisture loss is quite regular, although not so high as in essay 1 because the temperatures did not reach values of the same magnitude.
In Figure 2 the experimental points of the wet basis moisture content of the pears are plotted against the drying time (a) and the temperature of the surrounding air (b) for the 3 essays, together with the corresponding linear regression lines. From the graph (a) it can be seen that essay 1 is clearly distinguished from the other two, revealing a faster decrease in moisture and consequently a faster drying. The graph (b) shows that there is a direct relation between the drying temperature and the moisture of the pears, when expressed in a wet basis (g of water per 100 g of material).

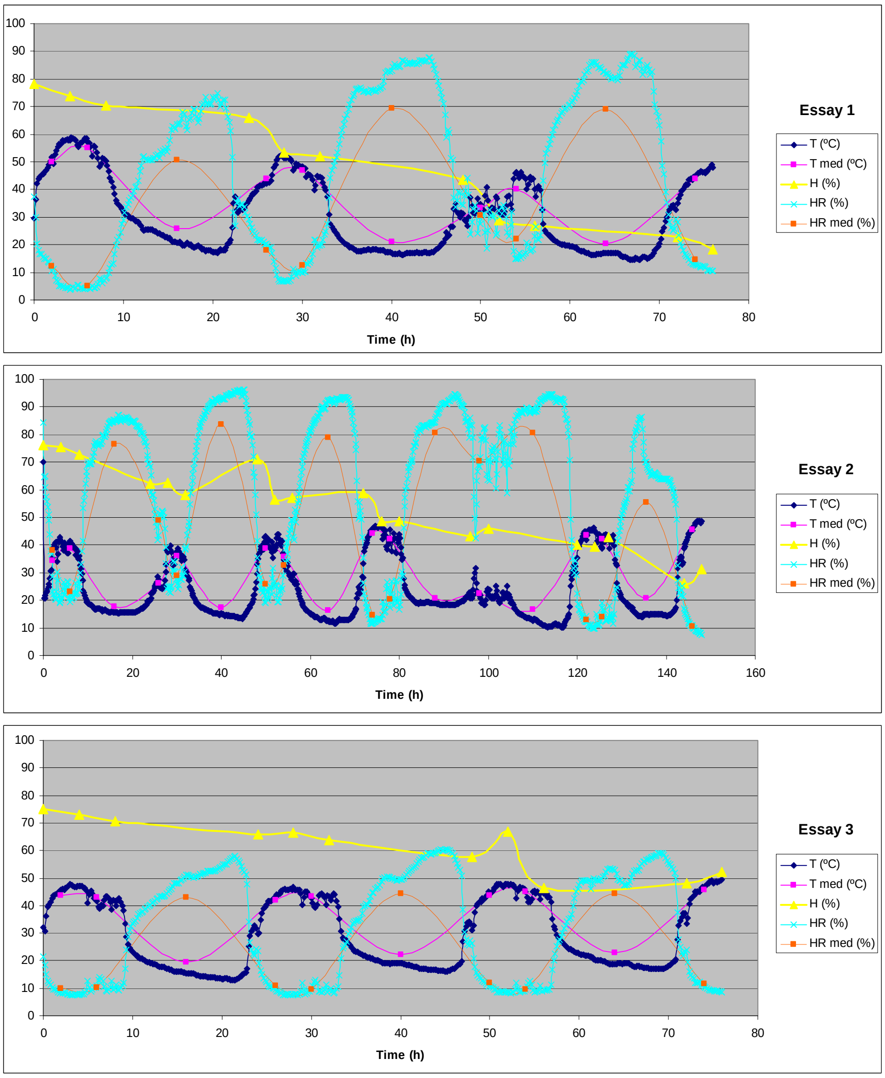

Figure 1 – Conditions inside the stove (temperature and relative humidity), in the three essays, and evolution of the moisture content of the pears.

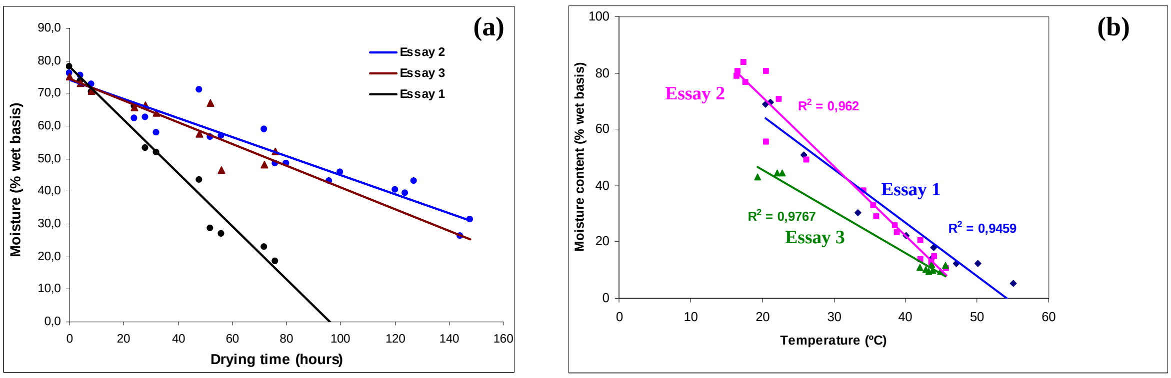

Figure 2 – Evolution of the drying process along time (a) and with temperature (b).

Figure 3 shows the experimental points of moisture ratio calculated for the 3 essays along with the corresponding fittings corresponding to the 6 models tested, and which were obtained with software SigmaPlot V8.0, SPSS, Inc.

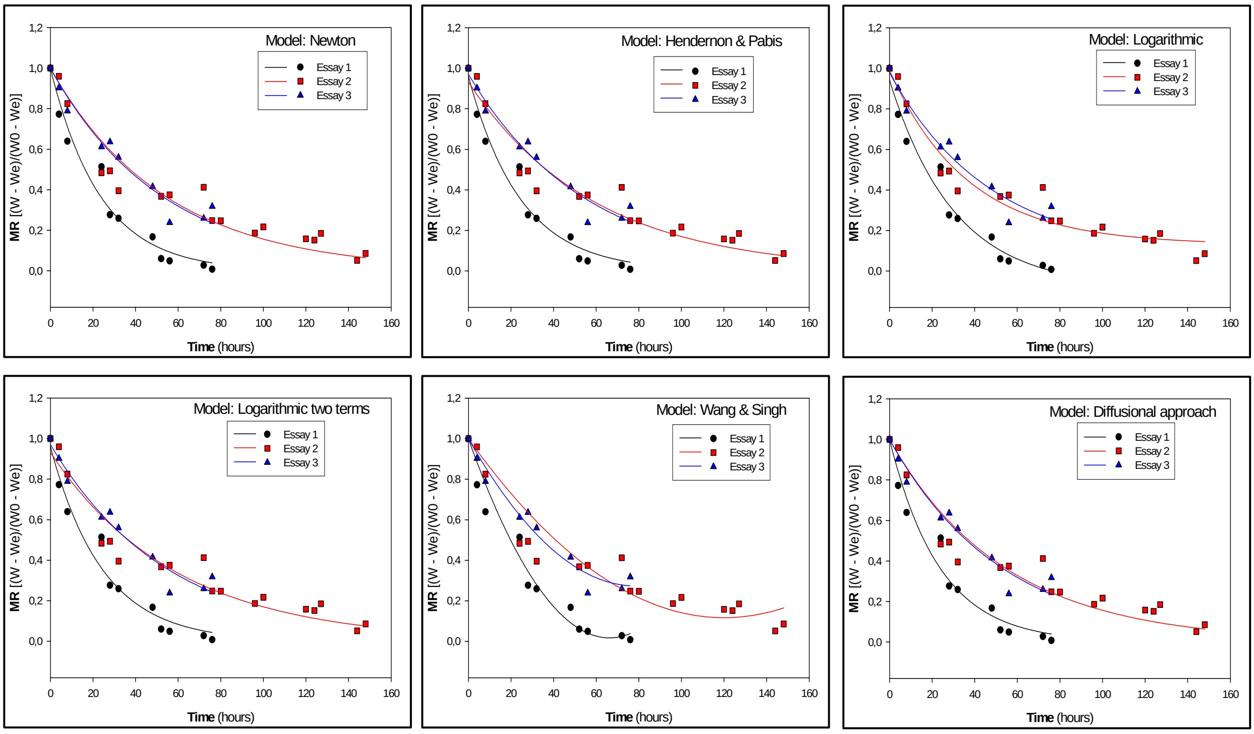

Figure 3 – Experimental points and fittings with the 6 different kinetic models.

From Figure 3 it can be observed once more that the drying rate is much faster in essay 1 when compared to the other two essays, as previously stated. As to the performance of the different models tested, all of them represent quite accurately the drying behaviour of these pears in the three drying essays.

4. CONCLUSIONS

From the results was possible to conclude that all the 6 models tested fit with accuracy the experimental data and that the differences found in the 3 essays result mainly from the climatic conditions in each drying period.

Acknowledgement
The authors thank the FCT – Fundação para a Ciência e Tecnologia, for financial support through project PTDC/AGR-ALI/74587/2006.

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