A study on the drying of food waste prior to the production of biochars through pyrolysis

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Drying of fruits and vegetables is a complex process, which requires heating the material in order to result in a transfer of moisture within the material to its surface, and subsequently the removal of water from the surface to the atmosphere (Akpinar & Bicer, 2005; Ekechukwu, 1999; Onwude, Hashim, Janius, Nawi, & Abdan, 2016). It is frequently used as a preservation technique to increase the shelf-life and improve product quality (Onwude et al., 2016). Other benefits of drying include reduction in the bulk and weight of dried products which reduces handling, packing and transportation costs. Furthermore, number of models have been developed for use in the calculations concerning the design and construction of new drying systems, optimization of the drying process, and the description of the whole drying process including the combined macroscopic and microscopic medium of mass and heat transfer (Onwude et al., 2016). It is therefore important to understand the basics of modeling the drying kinetics of fruits and vegetables. The thin-layer drying is one such example of a method widely used to determine the drying kinetics of fruits and vegetables. It consists of simultaneous heat and mass transfer operations. There is a pressing need for the use of the thin-layer modeling approach as a tool to estimate the drying kinetics from experimental data, describe the drying behaviour, improve the drying process, and most importantly minimize the total energy requirement. Moreover, the implementation of the thin-layer drying models in predicting the drying behaviour of fruits and vegetables usually involves the measurement of the moisture content of the material, which is done after the material has been subjected to different drying conditions (e.g. temperature, air velocity, and relative humidity) and the subsequent correlation with the dominant drying condition to estimate the model parameters.Thin-layer drying models are generally classified into three groups depending on their advantages and disadvantages and their derivation. The three groups are theoretical, semitheoretical and empirical models.

In recent years, the pyrolysis process has gained much attention due to the benefits of its application. The process produces three value-added products including biochar, bio-oil and biogas. Moreover, great amounts of food waste are producedworldwide and are associated with several societal and environmental issues that need to be resolved. Therefore, it is critical to find new and innovative solutions to this issue. The pyrolysis of biomass, and specifically food waste, is a promising waste management and handling technology. The ultimate aim of the current work is the production of biochars from food waste generated in the State of Qatar through the use of the pyrolysis process. In the first stage, selected food wastes are dried and prepared, in addition to analyzing the drying process. The food waste items include tomatoes, cucumber and rice. In this work, the temperature range is higher than the ones observed in the literature for studies involving the drying behaviour since the goal of them is mostly food preservation. The drying process is studied using temperatures in the range of 110 °C to 170 °C based on using low grade heat in exhaust heat transfer gases to remove the water before undergoing pyrolysis. This includes studying the diffusion behavior of each sample through selected mathematical models and running several experimental runs to compare the results. In this work, the experimental data were fitted to the Newton model and the Approximate Diffusion model.The Newton model is described by the following equation:

$$MR = \frac{M-M_e}{M_0-M_e} = \exp(-kt) \qquad \text{Eq. (1)}$$

where k is the drying constant (s^{-1}), MR is the moisture ratio, M is the dry basis moisture content at any time t, M0 is the initial dry basis moisture content of the sample, and Me is the equilibrium moisture content.

The Approximate Diffusion model, on the other hand, is given below:

$$MR = \frac{M-M_e}{M_0-M_e} = a * \exp(-kt) + (1-a) * \exp(-k * b * t) \qquad \text{Eq. (2)}$$

where a and b are dimensionless model constants.

The models were validated with experimentally measured data, and good agreement between the modelling and experimental results was found. The results for the tomato samples are presented in Figure 1 and Figure 2 below.

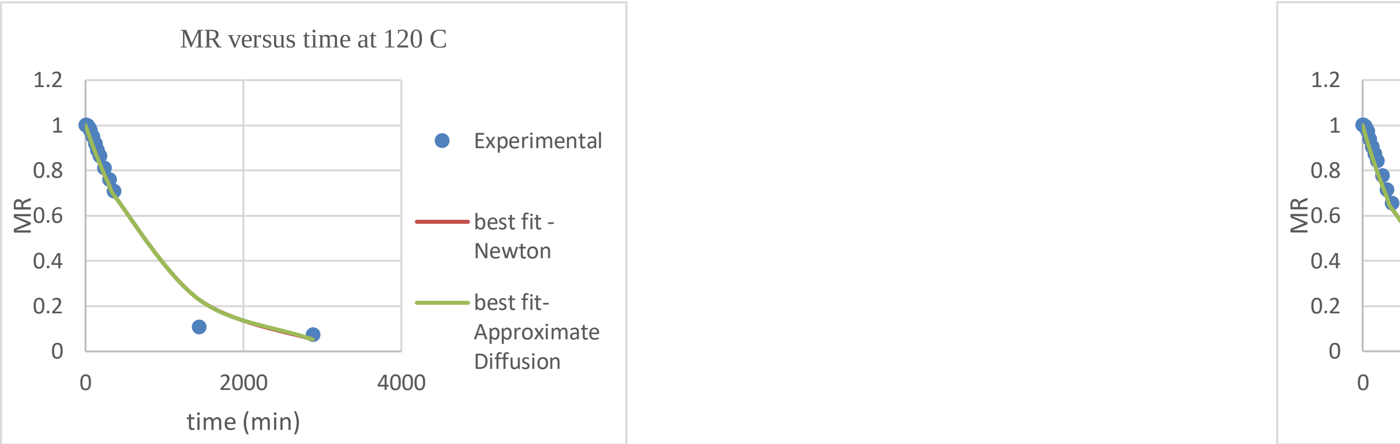

Figure 1. Drying results of whole tomato at 120 and 140 °C

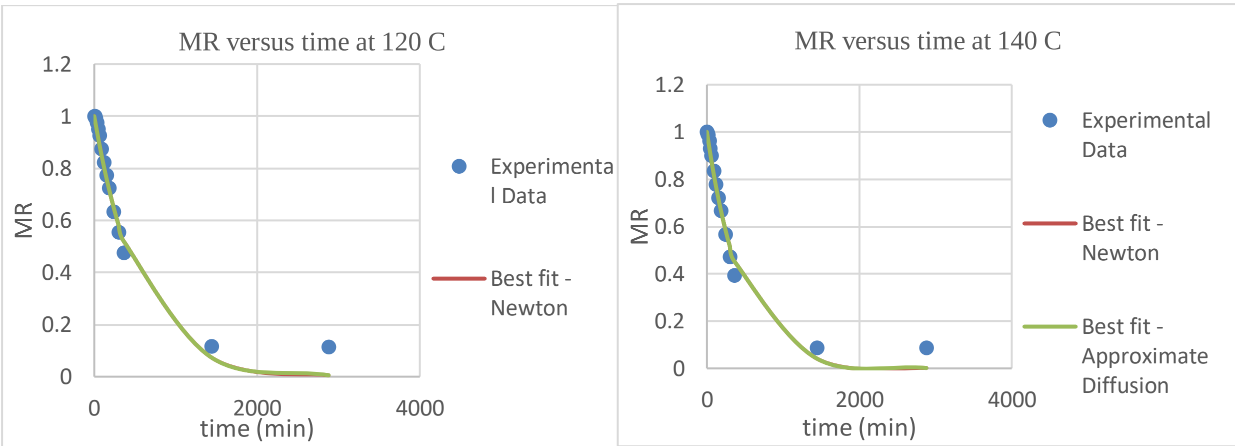

Figure 2. Drying results of half tomato at 120 and 140 °C

As can be seen in the figures, the moisture content of tomatoes decreased throughout the drying period. The drying was stopped at the 48th hour. Moreover, the drying data were used to calculate the non-dimensional MR, and as can be seen both the Newton and Approximate Diffusion models lie on top of each other indicating that there is an agreement between the two models.Plots satisfactorily describe the drying behaviour over the drying time range (0 min $\leq$ t $\leq$ 480 min), a range that represents the initial time of the drying process. Also, it can be seen from the figures that the samples achieved equilibrium moisture content. The drying rate increases with increase in heating rate and temperature. Deviation of some experimental data is due to experimental anomaly.

In conclusion, both models fitted the experimental results well during the initial stages of drying and showed an agreement in their results.The fit quality of the proposed models was evaluated using statistical tests including determination correlation coefficient, and root mean square. Furthermore, the modelling results of the three samples are presented, analyzed and discussed.

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