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Android Mobile Application for Modeling Solar Drying Kinetics

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Abstract- The application of Android and Communication Technologies to the engineering sector has increased notably in the last years. This work presents a new mobile software application for Modeling Solar Drying Kinetic named (SDK). The experimental data were transmitted by mobile from solar dryer in open air to a station of reception when they will be treated by our software application and the moisture ratio (MR) will be modeled with drying time. Coefficients of the models were determined by non-linear regression analysis and the models were compared based on their coefficient of determination (R^2), sum of square errors (SSE), root mean square error (RMSE) and chi-square (χ^2) between experimental and predicted moisture ratios. Drying curves can be also developed by this application and the effective moisture diffusivity (D_{eff}) can be calculated. In order to evaluate the application developed, it was tested on the thin layer solar drying of kiwifruit. The Page and the modified Page models were found to be the most suitable to describe the solar drying curves of Kiwifruit and the effective moisture diffusivity is 0.239410^{-12}m²/s. Therefore, the proposed android application can present comfortable usage and excellent tools for modeling solar drying kinetics.

Keywords: *Wireless Sensor Network, Android, Modeling, Kinetic, Solar Drying*

I. INTRODUCTION

The mobile communications are extremely relevant, and scientific community is aware of such relevance and many applications are under development in several science and engineering fields [1-3].

Installations become part of an integrated communications network. In turn, mobile devices, such as Pocket-Pcs, Smartphones or Tablet-Pcs, among others, are starting to be used as 'minicomputers' that are endowed with new communication possibilities, providing this way with some portability. These benefits make possible, for example, to acquire data from remote PV water pumping systems [4], or to monitor and control remotely complex stand-alone PV plants [5], even both of them by using the GSM.

Furthermore, the new generation of advanced operating systems, such as android, has facilitated the development of real-time applications that operate using large datasets processed by the device or a cloud server. This mode of operation is a key aspect of decision support [6-7] or tracing systems [8].Therefore, many sectors may benefit from the information generated by mobile devices to optimize systems and procedures.

Advances in this field are being achieved continuously, and several software applications developed in different domains can be found in literature. For instance, to serve as a base for solar site survey applications researcher [9] details investigation into the suitability of the Android Smartphone platform. Reference [10] study builds the system that allows users to plan their food consumption via their mobile phones. This system helps user to manage and tracking history of their food consumption, choosing food that suitable for their health, and help user to select their favorite restaurant. In medicine a system of health data collection, transmission and storage designed for electrocardiography (ECG) and Pulse Oximetry results was presented [11]. The goal is to address this challenge by creating a system for acquiring and transmitting data via Bluetooth to an Android mobile platform, which sends it to a remote server, where the data is stored in a database, and becomes available for visualization. Other works [12] present an analytical method for the calculation of the optimum inverter size in grid-connected PV plants in any location, and propose a benchmark tool [13] to estimate the cost-performance of a complete solar energy system by using computer aided modeling.

For the aforesaid reasons, this paper presents a new mobile software application named (SDK) for modeling solar drying kinetic by determining the moisture content and moisture ratio of samples with drying time. These parameters where calculated on using data transmitted by mobile from solar dryer in open air to a station of reception when they will be treated by the software application

II. MATERIALS AND METHODS

A. Calculation of the parameters

The software application proposed in this paper makes use of the provided time, instantaneous mass and initial moisture content sample to calculate the following parameters:

- MC(t) : Moisture content at time t,
- MR(t) : Moisture ratio at time t,
- DR(t) : Draying rate

- D_{eff} (m^2/s): Effective moisture diffusivity,

1) Determination of moisture content

The initial moisture content of sample was determined by the oven method. Samples were dried in the oven with the specific temperature at until constant mass was obtained.

The moisture content on dry basis MC (db) was calculated from Eq. (1) [14]:

$$MC(db) = (M_0 - M_d) / M_d \quad (1)$$

Where M_0 and M_d are the initial mass of the sample and the mass of the dried sample respectively.

2) Determination of moisture ratio

The dimensionless variable of moisture ratio (MR) of sample was calculated using the following equation:

$$MR\ (db) = (MC(t)\text{-}MC_e) / (MC_0 - MC_e) \quad (2)$$

Where X(t) is the moisture content at any time t; X0 is the initial moisture content, and Xe is the equilibrium moisture content. The values of Xe are relatively small compared to Xt and X0, hence the error involved in the simplification by assuming that Xe is equal to zero is negligible.

Thus the Eq. (2) can be written in a more simplified form as:

$$MR(db) = MC(t) / MC_0 \quad (3)$$

3) Drying rate

The drying rate is expressed as the amount of the evaporated moisture over time. The drying rate is calculated using the following equation (4):

$$DR = (MC_{t+\Delta t} - MC_t) / \Delta t \quad (4)$$

Where Xt+Δt is moisture content at time Δt+ t, t is the time and DR is the drying rate (kg water/kg dry matter. time).

4) Effective moisture diffusivity

Analytical solution of Fick's equation for an infinite slab (Eq.5) was used in order to estimate effective diffusivity [15].

$$Ln(MR) = Ln(8/\pi^2) - \pi^2 \times (2/L)^2\ D_{eff}.t \quad (5)$$

Where MR is the moisture ratio, D_{eff} is the effective diffusivity (m^2/s), t is the drying time (s) and L is the product leaf thickness (m).

Equation 5 was applied assuming one-dimensional moisture movement without volume change; a constant diffusivity, uniform moisture distribution and negligible external resistance.

B. Curves

This application can provide the curves of the moisture content, the moisture ratio and the drying rate with the drying time. The application can also provide the curve logarithm of the moisture ration with the drying time.

C. Mathematical modeling of the drying kinetics

Table 1 presents some models widely employed to describe the drying kinetics of vegetables.

The fitting steps were as follows:

The non-linear regression analysis was carried out by the curve fitting toolbox in our software android application to fit the equations to the experimental data in order to determine the coefficients of the equations.

Several criteria such as coefficient of determination (R^2); chi-square (χ^2); mean bias error (MBE) and root mean square error (RMSE) were used to determine the quality of the fit. These parameters are defined as follows [16]:

$$R^2 = 1 - \frac{\sum_{i=1}^{N}\left(MR_{pre,i} - MR_{exp,i}\right)^2}{\sum_{i=1}^{N}\left(MR_{pre,i} - \overline{MR}_{exp}\right)^2} \quad (6)$$

$$\chi^2 = [\sum_{i=1}^{N}(MR_{exp,i} - MR_{pred,i})] / (N - n) \quad (7)$$

$$MBE = [\sum_{i=1}^{N}(MR_{exp,i} - MR_{pred,i})] / N \quad (8)$$

$$RMSE = \sqrt{\left[\sum_{i=1}^{N}\left(MR_{exp,i} - MR_{pred,i}\right)^2\right] / N} \quad (9)$$

Where $MR_{pre,i}$ is the ith predicted moisture ratio, $MR_{exp,i}$ is the ith experimental moisture ratio, N is the number of observations and n is the number of constants in drying model.

Table 1 presents some models widely employed to describe the drying kinetics of vegetables.

TABLE I. MODELS EMPLOYED BY THE APPLICATION TO DESCRIBE THE DRYING KINETICS OF KIWIFRUIT.

Model no.	Name	Model equation	Coefficients of model	Reference
1	Newton	MR= exp(-kt)	K	[17-18]
2	Henderson and Pabis	MR= aexp(-kt)	a ; k	[19-20]
3	Page	MR= exp(-kt^n)	k ; n	[21]
4	Modified Page	MR= exp(-(kt)^n)	k ; n	[22]

D. Description of the application

The mobile software application presented in this paper has been designed with the aim of providing a functional and easy to-use tool to researcher for calculating solar drying kinetics parameters and modeling the moisture ratio (MR) with drying time. These data will help determining the conception of the solar dryer (SD).

The application has been developed for mobile devices that are endowed with either Android or Windows Mobile operating systems. The Android version has been developed using the Eclipse interface development environment (IDE) and the Android software development kit (SDK).

The graphical interface of the software developed consists of three tabs:

1- When the application is executed, the ‘‘Input’’ tab is initially shown (Fig. 1). In this screen the user can provide the application with initial data (instantaneous mass and time), which will be used later for estimating solar drying kinetics parameters (moisture content, moisture ratio, drying rate and logarithm of moisture ratio).

2- In the second tab (Fig. 2), the user can see the different drying curves (moisture content, moisture ratio and logarithm of moisture ratio versus drying time). Also the curve of drying rate with drying time can be seen.

3- In the third tab (Fig. 3), named ‘‘Models coefficients’’, the coefficients of models and coefficients of determination R^2, MBE, RMSE and χ^2 are shown.

Similarly, the time and date used for the estimations can either be captured from the mobile device or be introduced by the user.

Figure 1. The ‘‘Input’’ table for the initial data

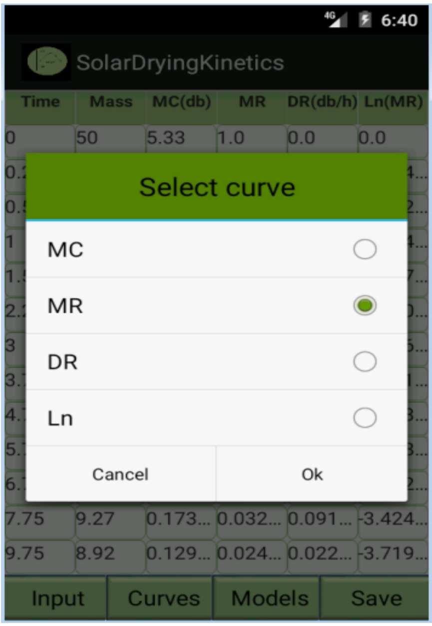

Figure 2. Interface for curves

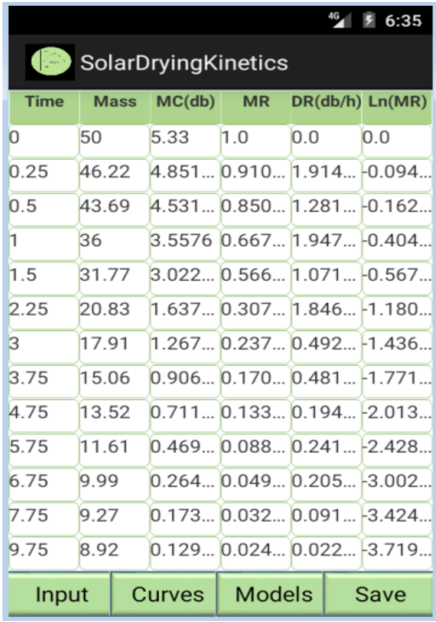

Figure 3. Instantaneous kinetics parameters calculated by the application

III. RESULTS AND DISCUSSES

In order to evaluate the application developed, it was tested on the thin layer solar drying of kiwifruit whose initial moisture content and thickness samples are 5.33 (db) and 4 mm, respectively.

Moisture content, moisture ratio, draying rate and logarithm of moisture ratio with drying time, calculated by the application were shown in Fig.3.

Using results from table (Fig.3), the kinetics curves are presented by the application. The curves of moisture content, moisture ratio and drying rate versus drying time are shown in figure 4.

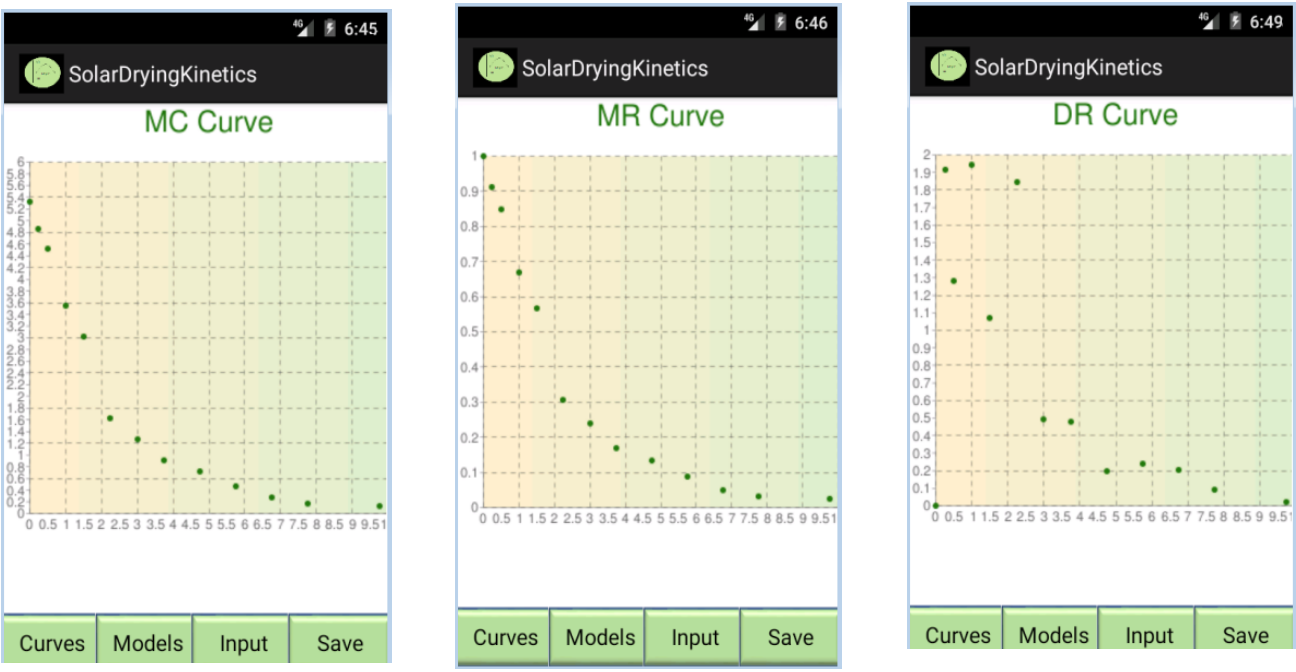

Figure 4. Curves of moisture content, moisture ratio and drying rate with drying time (h)

In order to calculate effective moisture diffusivity, the logarithm of moisture ratio curve versus drying time was also represented in figure 5. To model the variation of moisture ration with drying time curve of moisture ratio is fitted to four mathematical models described in table 1. Results presented in table (fig.6) show that the highest values of R` and the lowest values of MBE, RMSE and chi² can be obtained with the Page model and modified Page model.

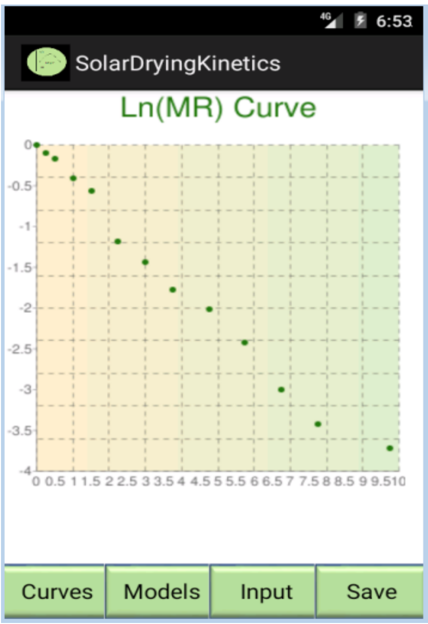

Figure 5. Logarithm of moisture ratio versus drying time (h)

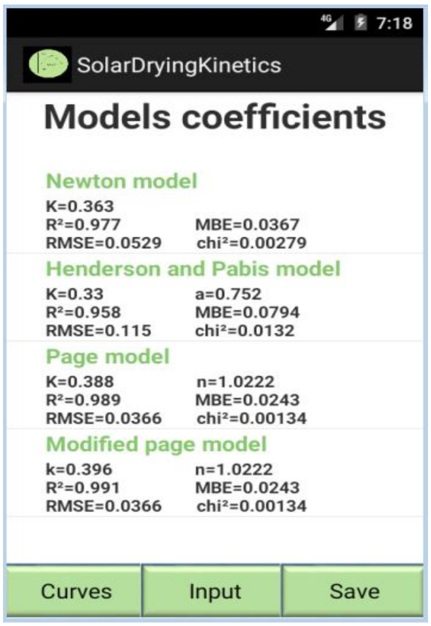

Figure 6. Models coefficients for moisture ratio according to drying time for kiwifruit and the different criteria of evaluation

To study the performance of the model a comparison between the MR measured for every drying time and the values estimated by the SDK application was illustrated in Fig.7. The predicted data generally band around the straight line representing experimental data, which indicates the suitability of these models in describing solar drying behavior of kiwifruit.

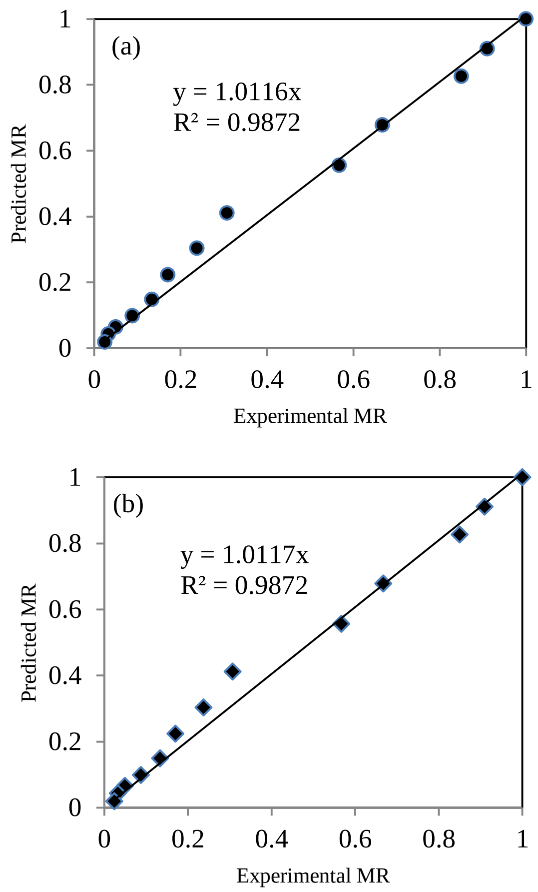

Figure 7. Comparison of experimental and predicted moisture ratio (solar drying) of kiwifruit by Page model (a) and by modified Page model (b)

IV. CONCLUSION

In this work, the Android application was implemented using the latest technologies in order to facilitate simple and easy modeling of solar drying kinetics. This application, named **SD**K, was tested on the thin layer solar drying of kiwifruit by determining moisture content, moisture ratio and effective moisture diffusivity for this product. The different drying curves were presented and moisture ratio was fitted to four different mathematical models and the results show that Page model and modified Page model have proved to be quite good to describe the drying behavior of kiwifruit slices in solar drying process. Therefore, the proposed mobile application can present comfortable usage and excellent tools for the study of solar drying kinetics.

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- R. F. Mechlouch, A. Ayedi. Sterilization of Naturally Contaminated Water with Solar Energy for remote villages, Revue des Régions Arides – Numéro spécial – 24 (2/ 2013).

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Conference Papers: 26

Citation Source Number of Citations: 54 citations (ResearchGate)

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(c) Service as Reviewer Journals

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- Journal of Food Process Engineering ISSN: (Online 1745-4530), Since 21 April 2015.

Research Interests:

Effects of drying processes on food quality, Effects of heat treatments on food quality, Renewable Energy