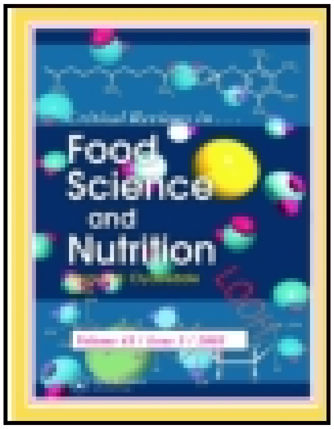

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A Comprehensive Review of Thin Layer Drying Models Used in Agricultural Products

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A Comprehensive Review of Thin Layer Drying Models Used in Agricultural Products

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Abstract

Drying is one of the widely used methods of grain, fruit and vegetable preservation. The important aim of drying is to reduce the moisture content and thereby increase the life time of products by limiting enzymatic and oxidative degradation. In addition, by reducing the amount of water, drying reduces the crop losses, improves the quality of dried products and facilitates its transportation, handling and storage requirements. Drying is a process comprising simultaneous heat and mass transfer within the material, and between the surface of the material and the surrounding media. Many models have been used to describe the drying process for different agricultural products. These models are used to estimate drying time of several products under different drying conditions, and how to increase the drying process efficiency and also to generalize drying curves, for the design and operation of dryers. Several investigators have proposed numerous mathematical models for thin layer drying of many agricultural products. This study gives a comprehensive review of more than 100 different semi-theoretical and empirical thin layer drying models used in agricultural products and evaluates the statistical criteria for the determination of appropriate model.

Keywords: moisture ratio; thin layer drying; food drying; drying models

1. Introduction

The drying of agricultural products has great importance to the mankind since ancient times. Thus, a large amount of study has been reported in the literature on drying of agricultural products. What is desired by engineers is a model that can predict the moisture content of the material for the given drying air conditions and also duration of exposure of the material to these conditions. In the development of thin layer models of agricultural products, the researchers generally measure the moisture content of the product at a known time after it has been subjected to a known and constant drying conditions.

Considerable amount of agricultural crops are dried artificially in different drying systems. Simulation models of these drying processes are used to design new or improve existing drying systems. The simulation of various drying systems involves solving a set of heat and mass transfer equations which describe (a) heat and moistre exchange between product and air, (b) adsorption and desorption rates of heat and moisture transfer, (c) equilibrium relations between product and air, and (d) psychrometric properties of moist air. Equations in group (a) are based on the governing laws of energy and mass conservation, and equations in group (d) are based on thermodynamic relations for mixture of dry air and water vapour. Equations in groups (b) and (c) are material dependent and their developments are based on experimental results. Because of the emprical nature of equations in groups (b) and (c), many different emprical equations have been developed based on the experimental data obtained using many different types of equipment. The variations among researchers in conducting experiments in data analysis and in reporting the

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results have limited the usefulness of thin layer drying data. The term “thin layer” has been applied to:

- A single kernel freely suspended in the drying air or one layer of grain kernels,
- A polylayer of many grain thicknesses if the temperature and the relative humidity of the drying air can be considered for the purpose of the drying process calculations, as being in the same thermodynamic state at any time of drying.

From this definition, it can be concluded that:

- Mathematical model of drying of a single grain kernel is also a model for grains drying in a thin layer using any of the drying methods,
- Thickness of a thin layer may change with the velocity, temperature and relative humidity of the drying air.

It means that, the thickness of a thin layer can increase if the velocity of the drying air increases and also if the thermodynamic state of the drying air approaches the equilibrium state in heat and mass transfer with grain dried in this layer (Jayas et al., 1991).

ASABE described “thin layer” as a layer of material exposed fully to an airstream during drying process and the thickness of the layer should be uniform and should not exceed three layers of particles (ASABE, 2001).

Thin layer drying equation is fundamental to the drying simulation. The equation represents moisture exchange between a thin layer of the drying product with its surrounding air. From a mathematical point of view, a thin layer represents the spatial dx that is choosen infinitesimal small within which changes in humidity and temperature of the air can be assumed linear (Wang et al., 2004).

The drying of biological products during the falling rate is controlled by the mechanism of liquid and/or vapor diffusion, provided that the resistance to moisture flows is uniformly distributed throughout the interior of the homogeneous isotropic material. The rate of moisture movement is described by an effective diffusivity value, D_{eff}, no matter which mechanism of diffusion is involved (Hui et al., 2008). The Fick's second law of diffusion is often used to describe a moisture diffusion process (Crank, 1975);

$$\frac{\partial m}{\partial t} = D_{eff}\, \nabla^2 m$$

where, m is the local moisture content on a dry basis (d.b.), t is the time (s) and D_{eff} is the moisture diffusivity ($m^2.s^{-1}$). This equation can be expanded into cartesian, cylindirical or spherical coordinates by appropriate laplacian operators (Pabis et al., 1998).

In most situations, the food product is assumed as one-dimensional and has a uniform initial moisture content. The assumptions involved in the diffusion analysis are: internal moisture movement as the main resistance, no shrinkage in the product during drying and negligible external and internal heat transfer effect. The solutions of the Fickian equation under such conditions for different geometries have been presented by Crank (1975) and Luikov (1968) (Devahastin, 2000). The solution of Fick's equation for an infinite slab is as follows:

$$MR = \frac{M - M_e}{M_0 - M_e} = \frac{8}{\pi^2}\sum_{n=0}^{\infty}\frac{1}{\left(2n+1\right)^2} exp\left[-\left(2n+1\right)^2 \frac{\pi^2 D_{eff}\, t}{L^2}\right]$$

where M is moisture content of a product measured or calculated during drying, expressed on dry basis, M_o is moisture content of a product prior to the start of drying, expressed on dry basis, M_e is moisture content of a product in equilibrium with mean dry bulb temperature and relative humidity of the drying air, expresses as dry basis and L is the thickness of the slab (m) (ASABE, 2001). The following equations are solutions for the cases of an infinite cylinder and sphere, respectively;

$$MR = \frac{M - M_e}{M_0 - M_e} = \sum_{n=0}^{\infty} \frac{4}{b_n^2} exp\left[- \frac{b_n^2 \pi^2 D_{eff}\, t}{r_c^2} \right]$$

$$MR = \frac{M - M_e}{M_0 - M_e} = \frac{6}{\pi^2} \sum_{n=0}^{\infty} \frac{1}{n^2} exp\left[-n^2 \frac{\pi^2 D_{eff}\, t}{r_s^2} \right]$$

where, b_n, n=1,2 … are constants, and r_c is the radius of cylinder (m) and r_s is the radius of sphere (m) (Hui et al., 2008). This equation could also be solved for prolate and oblate spheroiid, cardioid, hexagon, corrugated and epitrochoid shapes (Kahveci and Cihan, 2008). It is possible to obtain analytical solutions of the diffusion equation for some simple geometries under certain assumptions. Suppose that;

- The diffusion coefficient is independent of moisture content for a given temperature,
- The material is isothermal during drying,
- The moisture is initially uniformly distributed throughout the material,
- The surface moisture content of the samples instantaneously reaches equilibrium with the condiitons of surrounding air,
- The material size and geometry remain constant during drying,
- There is no mass generation or depletion inside the material (Kahveci and Cihan, 2008).

Drying is a process of simultaneous heat and moisture transfer. The heat is required to evaporate the moisture which is removed from the drying product surface by the external drying medium, usually air. A number of biological products, when drying as single particles under constant external conditions, exhibit a constant rate moisture loss during initial drying period, followed by a falling rate drying period. These products usually dry entirely within the falling rate period. During this period, the surface of a drying particle is not covered with a thin layer water, because the internal resistance to moisture transport has become greater than the external resistance. The agricultural products usually dry solely during the falling rate period. This implies that, the drying rate decreases continuously during the course of drying. Prediction of the drying rate of a biological product is more complicated during the falling rate period than during the constant rate period. Not only do the external transfer mechanisms have to be considered in the analysis, but the transfer mechanisms within the product must also be included. There are theoretical, semi-theoretical and empirical relationships to predict the drying behaviour of different products in the falling rate drying period. Only the semitheoretical and empirical models have proved useful for the dryer designers (Brooker et al., 1974).

A semi-theoretical drying model is based on the diffusion theory, assuming that the resistance to water diffusion in a product occurs in the outer layer of the product. Thus, using Newton's law of cooling and assuming a similarity between the cooling and drying of a solid body, the following expression can describe the drying rate;

$$\frac{\partial M}{\partial t} = -k\left(M - M_e\right)$$

where k is drying coefficient, M_e is equilibrium moisture content of a product and M is average moisture content of a product (Pabis et al., 1998).

Empirical drying models often give the best results in predicting drying behaviour. The equations can be employed with confidence within the temperature, relative humidity, air flow velocity and moisture content range for which they were derived (Brooker et al., 1974). These models can be used in automatic controls of drying processes for economy and short calculation time (Pabis et al., 1998). The empirical models constitute a direct relationship between the average moisture content and drying time. They neglect the fundamentals of the drying process and therefore their parameters have no physical meaning.

The semi-theoretical models are generally derived by simplifying general series of Fick's second law or are modified forms of simplified models. The empirical and semi-theoretical models require small amounts of time compared to theoretical models and do not require assumptions of the geometry of a typical food or its mass diffusivity and conductivity. Therefore, they are useful for automatic control processes (Kahveci and Cihan, 2008).

In this study, semi-theoretical and empirical models used in different literatures for different materials and also statistical methods for evaluation of these models were given in detail.

2.1 Semi Theoritical Models

2.1.1 Models Derived From Newton's Law of Cooling

2.1.1.1 Lewis model

Lewis described that, the moisture transfer from agricultural materials can be seen as similar to the law of heat from a body immersed in cold fluid. By comparing this phenomenon with Newton's law of cooling, the drying rate is proportional to the difference between actual and equilibrium moisture content;

$$dM / dt = -k\left(M - M_e\right)$$

Newton's law of cooling assumes that, the internal resistance to moisture movement and thus moisture gradients within the material are negligible. It considers only the surface resistance

(Madamba, 2003). Assuming a boundary condition as $M=M_0$ at $t=0$, the solution of the above equation is known as Lewis, Newton, Simple or Exponential model;

$$MR = exp\left(-k\,t\right)$$

where k is the drying constant (s^{-1}). This is one of the simplest models describing moisture movement for food products. The most important drawback of this model is that, it generally underestimates late stages and overestimates early stages of the drying process (Vijayaraj et al, 2007; Ghazanfari et al., 2006a; Madamba, 2003; Wongwises and Thongprasert, 2000; Hossain and Bala, 2002).

This model has been widely and successfully used by some researchers to model the drying behavior of agricultural products such as strawberry (El-Beltagy et al., 2007), red chilli (Hossain et al., 2007), grape seeds (Roberts et al., 2008) and black tea (Panchariya et al., 2002).

2.1.1.2 Page model

This model is an empirical modification of Lewis model to eliminate the shortcomings of that model by adding a dimensionless empirical constant (n) to the time term. This parameter has an effect of moderating the time, and the model in this case gives better results for the prediction of moisture loss (Kahveci and Cihan, 2008; Doymaz and Ismail, 2011);

$$MR = exp\left(-k\,t^n\right)$$

This model has been used by many researchers to describe the rate of moisture loss during thin layer drying of agricultural materials under constant drying conditions. It was successfully used to describe the drying characteristics of some agricultural products such as tomato (Doymaz, 2007a), wheat (Rafiee et al., 2008), dates (Hassan and Hobani, 2000) and barberries (Aghbashlo et al., 2007).

2.1.1.3 Modified Page model

There were some different modifications in the Page model and they were tested for describing the drying behavior of different agricultural products;

Modified Page-I $MR = exp\left[\left(-k\,t\right)^{n}\right]$ the best for sesame hull (Al-Mahasneh et al., 2007)

Modified Page-II $MR = exp\left[-\left(k\,t\right)^{n}\right]$ the best for mint and basil leaves (Akpinar, 2006a), aloe vera (Vega et al., 2007), papaya (Lemus-Mondaca et al., 2009)

Modified Page-III $MR = exp\left[-\left(-k\,t\right)^{n}\right]$ the best for sweet potato slices (Falade and Solademi, 2010)

Modified Page-IV $MR = a\,exp\left[-\left(k\,t^{n}\right)\right]$ tested for figs (Babalis et al., 2006)

Modified Page-V $MR = exp\left[-\left(k\,t^{n}\right)\right]$ tested for plums (Jazini and Hatamipour, 2010)

Modified Page-VI $MR = exp\left(k\,t^{n}\right)$ tested for mushrooms (Kurozawa et al., 2012)

Addition of another empirical coefficient “L” (thickness) in Page equation gives the different Modified Page equations and they were tested for different agricultural products;

Modified Page-VII $MR = exp\left[-k\left(t / L^{2}\right)^{n}\right]$ tested for mushroom and chili (Artnaseaw

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		et al., 2010a), red beet (Kaleta and Gornicki, 2010), jujube (Fang et al., 2009) and black grape (Togrul, 2010)
Modified Page-VIII	$MR = exp\left\{-\left[k\left(t/L^2\right)\right]^n\right\}$	tested for soy-fortified wheat based ready to eat snacks (Pardeshi and Chattopadhyay, 2010)
Modified Page –IX	$MR = k\,exp\left[\left(-t/L^2\right)^n\right]$	the best for onion slices (Kumar et al., 2006)

2.1.1.4 Otsura et al. model

Otsura et al. model was quite similar to Page's equation and used for thin layer drying of rough rice (Otsura et al., 1975 from Chen and Wu, 2001);

$$MR = 1 - exp\left[-\left(k\,t^n\right)\right]$$

2.1.2 Models Derived From Fick's Second Law of Diffusion

2.1.2.1 Simplified Fick's model

A simplified solution of Fick's diffusion equation valid for long drying times is (Kumar et al., 2006);

$$MR = k\,exp\left[-c\left(t/L^2\right)\right]$$

This model was tested to model the drying of bay leaves (Gunhan et al., 2005), apricot (Togrul and Pehlivan, 2003) and apple (Togrul, 2005).

2.1.2.2 Henderson and Pabis model

The Henderson and Pabis model is the first term of a general series solution of Fick's second law;

$$MR = a\,exp\left(-k\,t\right)$$

This model effectively predicts the drying rate at the beginning of the drying process, but appears sometimes to be less efficient for the last stages of the process (Dissa et al., 2008). This model was used successfully to model drying of African breadfruit seed (Shittu and Raji, 2011), banana, mango and cassava (Koua et al., 2009) and onion (Sawhney et al., 1999). The slope of this model, "*k*", is related to effective diffusivity when drying process takes place only in the falling rate period and liquid diffusion controls the process (Panchariya et al., 2002).

2.1.2.3 Modified Henderson and Pabis model

This model is improved by adding the third term of the general series solution of Fick's second law of diffusion for correcting the shortcomings of the Henderson and Pabis model. It was emphasized that, the first part explains the latest part, the second term explains the intermediate part and the third term explains the beginning part of moisture ratio and time curve as (Erbay and Icier, 2009);

Modified Henderson and Pabis-I $$MR = a\,exp\left(-k_0\,t\right) + b\,exp\left(-k_1\,t\right) + c\,exp\left(-k_2\,t\right)$$

This model is successfully used for pistachio (Aktas and Polat, 2007), kiwifruit (Doymaz, 2009a) and coconut (Madhiyanon et al., 2009) to determine the drying behavior. There is also another form of Modified Henderson and Pabis model tested for mango as (Corzo et al., 2011);

Modified Henderson and Pabis-II $$MR = a\,exp\left(-k\,t^n\right) + b\,exp\left(-g\,t\right) + c\,exp\left(-h\,t\right)$$

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2.1.2.4 Logaritmic model

This model is in logarithmic form of Henderson and Pabis model with an addition of an empirical term (Erbay and Icier, 2009);

$$MR = a\,exp\left(-k\,t\right) + c$$

This model is widely used for thin layer drying studies. It has produced good fits in predicting drying of green bell pepper (Doymaz and Ismail, 2010), pineapple (Kingsly et al., 2009), peach (Kingsly et al., 2007), barbunya bean (Kayisoglu an Ertekin, 2011) and white mulberry (Doymaz, 2004a).

2.1.2.5 Two Term model

This model is the first two terms of general series solutions to the analytical solution to the diffusion equation of Fick's second law. This solution applies regardless of particle geometry and boundary conditions, but assumes that diffusivity is constant and requires constant product temperature during drying (Kumar et al., 2006; Kashaninejad et al., 2007; Panchariya et al., 2002; Dandamrongrak et al., 2002). It is shown as;

$$MR = a\,exp\left(-k_0\,t\right) + b\,exp\left(-k_1\,t\right)$$

This model predicts the moisture transport well and its parameters represent the physical properties of the drying process. It is successfully applied to explain drying behavior of prickly pear fruit (Lahsasni et al., 2004a) and cladodes (Lopez et al., 2009), sultana grapes (Yaldiz et al., 2001), garlic (Sacilik and Unal, 2005) and pumpkin (Zenoozian et al., 2008).

2.1.2.6 Modified Two Term model

Modifications of two term model to the different forms were given below;

Modified two term-I $MR = a\,exp\left(k_0\,t\right) + \left(1 - a\right)exp\left(-k_1\,t\right)$ tested for celery leaves (Demirhan and Ozbek, 2011)

Modified two term-II $MR = a\,exp\left(k_0\,t\right) + \left(1 - a\right) exp\left(k_1\,t\right)$ tested for spinach (Dadali et al., 2007a)

Modified two term-III $MR = a\,exp\left(-k_0\,t\right) + a\,exp\left(-k_1\,t\right)$ tested for banana (Baini and Langrish, 2007)

Modified two term-IV $MR = a\,exp\left(-k_0\,t^n\right) + b\,exp\left(-k_1\,t\right)$ tested for paddy (Tirawanichakul et al., 2008)

Modified two term-V $MR = a\,exp\left(-k_0\,t\right) + \left(1 - a\right) exp\left(-k_1\,t\right)$ tested for rough rice (Chen and Wu, 2001)

2.1.2.7 Two-Term Exponential model

This model is the first two terms of general series solution to the analytical solution of Fick's second law. The two-term model was modified by decreasing the constant number and organising the second exponential term. It was emphasized that, "*b*" coefficient in the two term model has to be (*1 –a*) at *t*=0 to get *MR*=1 and this new model is proposed as (Doymaz, 2006; Erbay and Icier, 2009);

$$MR = a\,exp\left(-kt\right) + \left(1 - a\right) exp\left(-k\,a\,t\right)$$

This model is tested for pistachio (Midilli and Kucuk, 2003), leek (Doymaz, 2008a) and radish (Lee and Kim, 2009).

2.1.2.8 Verma et al. model

The two-term exponential model is modified by adding an empirical constant and successfully applied for the drying of rice (Verma et al., 1985 from Erbay and Icier, 2009), parsley (Akpinar et al., 2006), fig (Doymaz, 2005) and coffee (Resende et al., 2009);

$$MR = a\,exp\left(-k\,t\right) + \left(1-a\right)exp\left(-g\,t\right)$$

2.1.2.9 Diffusion Approximation model

After re-arrangement of Verma et al. model by separating the drying constant term "*k*" from "*g*", the new model is obtained as (Erbay and Icier, 2009);

$$MR = a\,exp\left(-kt\right) + \left(1-a\right)exp\left(-k\,bt\right)$$

This model was successfully used to model the drying of tomato (Sacilik et al., 2006), red pepper (Akpinar et al., 2003), pumpkin and green pepper (Yaldiz and Ertekin, 2001) and yam slices (Sobukola et al., 2008).

2.1.2.10 Midilli et al. model

Midilli et al. model is composed of an exponential and a linear term describing the moisture ratio as a function of drying time;

$$MR = a\,exp\left(-k\,t^{n}\right) + b\,t$$

This model is also similar to Henderson and Pabis model with an addition of an empirical term to "*t*" (Ghazanfari et al., 2006a; Doymaz, 2008b; Midilli et al., 2002). The Midilli et al. model was successfully used in studying the drying characteristics of agricultural products such as savory leaves (Arslan and Ozcan, 2012), purslane (Demirhan and Ozbek, 2010a) and eggplant (Ertekin and Yaldiz, 2004).

2.1.2.11 Modified Midilli et al. model

When the instantaneous moisture content is equal to equilibrium moisture content at the beginning of the drying process, the coefficient in Midilli et al. model must be equal to 1. So, the Modified Midilli et al. model is tested for flax fiber and is given as follows (Ghazanfari et al., 2006a);

Modified Midilli et al.-I $MR = exp\left(-k\,t^{n}\right) + b\,t$

The shape term "*a*" of the Midilli et al. model had to be 1 at *t*=0 and proposed a modification as (Ghazanfari et al., 2006a from Erbay and Icier, 2009);

Modified Midilli et al.-II $MR = exp\left(-k\,t\right) + b\,t$

Another form of Modified Midilli et al. model is tested for kiwifruit (Doymaz, 2009a);

Modified Midilli et al.-III $MR = a\,exp\left(-k\,t\right) + b\,t$

2.2 Empirical Models

2.2.1 Wang and Singh model

Wang and Singh proposed a new quadratic equation to fit the single layer data of rough rice (Chen and Wu, 2001);

$$MR = 1 + a\,t + b\,t^{2}$$

It was successfully used to explain drying behaviour of banana (Kadam and Dhingra, 2011), parsley leaves (Akpinar, 2011) and bamboo shoot slices (Bal et al., 2010).

2.2.2 Thompson model

Thompson et al. (1968) proposed the below empirical equation to describe the drying curve of shelled corn (Chen and Wu, 2001);

$$t = a\,ln\left(MR\right) + b\left[ln\left(MR\right)\right]^2$$

This model was also used to describe the drying characteristics of green peas (Pardeshi et al., 2009) and blueberries (Shi et al., 2008).

2.2.3 Hii et al. model

Hii et al. proposed a new model consisting of Page and two term drying models. A power term "*n*" is introduced for the time "*t*";

$$MR = a\,exp\left(-k\,t^n\right) + c\,exp\left(-g\,t^n\right)$$

This model was encountered by previous experience that these Page and two term models when used individually often produced reasonable fitting for drying data with inclusion of tempering (Hii et al., 2009). This model is used for coffee (Varadharaju et al., 2001), carrot pomace (Kumar et al., 2012) and cocoa (Hii et al., 2008 and 2009) satisfactorily.

2.2.4 Weibull Distribution models

This model has not got any physical meaning; it is a purely statistical approach. A model based on Weibull distribution is shown below and tested for fig (Babalis et al., 2006) and jujube (Yi et al., 2012);

Weibull distribution-I $\quad MR = a - b\,exp\left[-\left(k\,t^n\right)\right]$

There are two more different forms of Weibull distribution models;

Weibull distribution-II $\quad MR = a - b\,exp\left[-k\,t^n\right]$ tested for pomegranate arils (Mundada et al., 2010).

Weibull distribution-III $\quad MR = exp\left[-\left(t/a\right)^n\right]$ is successfully used for sour cherry

(Aghbashlo et al., 2010), mango (Corzo et al., 2010) and quinoa (Vega-Galvez et al., 2010).

2.2.5 Vega-Galvez et al. models

Vega-Galvez et al. (2008) proposed three different empirical models to describe drying of red pepper;

Vega-Galvez et al.-I $MR = n + k\sqrt{t}$

Vega-Galvez et al.-II $MR = exp\left(n + k\,t\right)$

Vega-Galvez et al.-III $MR = \left(a + b\,t\right)^2$

The third model is used mainly because of the simplicity to calculate the drying time of the material and also to present two parameters which provide accuracy to the experimental data. It is tested for yellow squat lobster fishery waste (Vega-Galvez et al., 2009a) and pumpkin (Guine et al., 2012).

2.2.6 Jena Das model

In this model, two exponential terms of drying time have been incorporated. The values of exponent in the first and second terms of the model were kept constant as 1.0 and 0.5 for simplicity, respectively. This model is proposed to overcome the negative effect of changing diffusivity on moisture content and successfully used for coconut presscake drying (Jena and Das, 2007);

$$MR = a\,exp\left(-k\,t + b\sqrt{t}\right) + c$$

2.2.7 Wang et al. models

They proposed three different models (Wang et al., 2004);

One term $MR = a\,exp\left(b\,k\,t\right) + \left(1 - a\right)$

Two term $MR = \left(1 - a\right) exp\left(b\,k\,t\right) + a\,exp\left(c\,k\,t\right)$

Three term $MR = \left(1 - a - b\right) exp\left(c\,k\,t\right) + a\,exp\left(d\,k\,t\right) + b\,exp\left(f\,k\,t\right)$

2.2.8 Demir et al. model

Demir et al. proposed a new model by using curve fitting procedure which is similar to Page, Logaritmic and Midilli et al. models as (Demir et al., 2007);

$$MR = a\,exp\left[\left(-k\,t\right)^{n}\right] + b$$

This model is successfully used for green table olives.

2.2.9 Diamente et al. model

The proposed model is a quadratic equation of the following form and successfully used for kiwifruit and apricot (Diamente et al., 2010):

$$ln\left[-ln\left(MR\right)\right] = a + b\,ln\left(t\right) + c\left[ln\left(t\right)\right]^{2}$$

2.2.10 Haghi and Angiz models

The below model is successfully used for drying of wool (Haghi and Angiz, 2007);

Haghi and Angiz-I $MR = a\,exp\left(-b\,t^{c}\right) + d\,t^{2} + e\,t + f$

They also examined different models such as;

Haghi and Angiz-II $MR = a + b\,t + c\,t^{2} + d\,t^{3}$

Haghi and Angiz-III $MR = \dfrac{a + b\,t}{1 + c\,t + d\,t^{2}}$

Haghi and Angiz-IV $$MR = a\,exp\left[\frac{-\left(t-b\right)^2}{2c^2}\right]$$

2.2.11 Sripinyowanich and Noomhorm model

This model was developed based on a general grain drying model, namely, the Page model and a simple linear type equation. This model adjusts well to the behavior of moisture loss during the last falling rate period. It was successfully used for drying of rice (Sripinyowanich and Noomhorm, 2011);

$$MR = exp\left(-k\,t^n\right) + b\,t + c$$

2.2.12 Noomhorm and Verma model

They proposed below model for rough rice (Noomhorm and Verma, 1986 from Kaleta and Gornicki, 2010);

$$MR = a\,exp\left(-k\,t\right) + b\,exp\left(-g\,t\right) + c$$

2.2.13 Hasibuan and Daud model

They used the following model, which fits both the increasing drying rate and the falling rate periods;

$$MR = 1 - a\,t^n\,exp\left(-k\,t^m\right)$$

This model is tested for kenaf fibers ([Hasibuan and Daud, 2004 from Daud et al., 2007).

2.2.14 Sharaf-Eldeen et al. model

Sharaf-Eldeen et al. proposed below model for frying of ear corn (Sharaf-Eldeen et al., 1980 from Wang et al., 2004);

$$MR = a\,exp\left(k\,t\right) + \left[1 - a\,exp\left(-b\,k\,t\right)\right]$$

2.2.15 Henderson and Henderson models

These models are simplifications of the analytical solution of the diffusional model;

Henderson and Henderson-I $MR = c\left[exp\left(-k\,t\right)+\frac{1}{9}exp\left(-9\,k\,t\right)\right]$ (Henderson and Henderson, 1968 from Barrozo et al., 2004)

Henderson and Henderson-II $MR = c\,exp\left(-k\,t\right)+\frac{1}{9}exp\left(-9\,k\,t\right)$ (Henderson and Henderson, 1968 from Lima and Massarani, 1995)

2.2.16 Parabolic model

This model is in quadratic form and given as;

$$MR = a + b\,t + c\,t^2$$

It was tested for African breadfruit seeds (Shittu and Raji, 2011), thyme (Doymaz, 2011a) and seedless and seeded grapes (Doymaz, 2011b), and successfully used for apple (Doymaz, 2010).

2.2.17 Geometric model

This model is tested for rice (Hacihafizoglu et al., 2008), mushroom (Celen et al., 2010) and onion (Jain and Pathare, 2004);

$$MR = a\,t^{-n}$$

2.2.18 Logistic model

This model is examined for parsley (Soysal et al., 2006), bamboo sheet (Bal et al., 2010) and rice (Cihan et al., 2007);

$$MR = a_0 / \left[1 + a\,exp\left(k\,t\right)\right]$$

2.2.19 Power Law model

This power law model is tested for sweet pepper (Vengaiah and Pandey, 2007) and pomegranate peel (Emam-Djomeh et al., 2007);

$$MR = a\,t^b$$

2.2.20 Regression models

These models are tested for bluberries (Shi et al., 2008);

Regression-I $\quad MR = exp\left[-\left(a\,t^2 + b\,t\right)\right]$

Regression-II $\quad t = a\left(MR\right)^2 + b\left(MR\right) + c$

2.2.21 Chavez-Mendez et al. model

This is mentioned as logaritmic model and tested for chilli pepper (Tunde-Akintunde, 2011), banana (Sankat et al., 1996) and described as the best model for sweet pepper (Vengaiah and Pandey, 2007);

$$MR = a + b\,ln\left(t\right)$$

2.2.22 Aghbashlo model

This model is tested for pistachio (Chayjan et al., 2012), tomato (Garavand et al., 2011), apple (Meisami-Asl and Rafiee, 2009) and described the drying behaviour of carrot satisfactorily (Aghbashlo et al., 2009);

$$MR = \exp\left[-\frac{k_1\,t}{\left(1 + k_2\,t\right)}\right]$$

2.2.23 Modified Henderson and Perry model

It was tested for mango (Chottanom and Phoungchandang, 2005) and popcorn (Ademiluyi et al., 2008);

$$MR = a\,exp\left(-k\,t^{n}\right)$$

2.2.24 Three Parameter model

This model is satisfactorily described the drying process of popcorn (Ademiluyi et al., 2008) and sweet basil (Phoungchandang and Kongpim, 2012);

$$MR = a\,exp\left[-\left(k\,t\right)^{n}\right]$$

2.2.25 Asymptotic model

It was successfully used for onion (Jain and Pathare, 2004);

$$MR = a_{o} + a\,exp\left(-k\,t\right)$$

2.2.26 Alibas model

This model derived from the approximation of Midilli et al. model as (Alibas, 2012);

$$MR = a\,exp\left[\left(-k\,t\right)^{n} + bt\right] + g$$

2.2.27 Khazaei and Daneshmandi model

This model is tested for sesame seeds and presented as (Khazaei and Daneshmandi, 2007);

$$MR = a + exp\left(-b\,t\right) - c\,t$$

2.2.28 Growth curve models

In a separate study (Siatkowski et al., 2010), 37 different growth curve functions were tested to model corn drying process. These functions were given below:

- Baroreflex five-parameter function:

baro5

$$MR = c + \frac{d-c}{1+ f\exp\left\{(b_1\left[\log(t)-\log(e)\right]\right\} + (1-f)exp\left\{b_2\left[log(t)-log(e)\right]\right\}}$$

where $f = \frac{1}{1+exp\left\{\frac{2b_1b_2}{b_1+b_2}\left[log(t)-log(e)\right]\right\}}$

- Brain-Cousens modified log-logistic functions:

BC.4 $$MR = \frac{d+ft}{1+exp\left\{b\left[\log(t)-log(e)\right]\right\}}$$

BC.5 $$MR = c + \frac{d-c+ft}{1+exp\left\{b\left[log(t)-log(e)\right]\right\}}$$

- Four parameter Cedergreen-Ritz-Streibig modified log-logistic functions:

CRS.4a; α=1 $$MR = \frac{d+f\exp\left(-1/t^{\alpha}\right)}{1+exp\left\{b\left[log(t)-log(e)\right]\right\}}$$

CRS.4b; α=0.5

CRS.4c; α=0.25

- Four parameter Cedergreen-Ritz-Streibig modified log-logistic functions for describing u-shaped hormesis:

UCRS.4a; α=1 $$MR = d - \frac{d+f\,exp\left(-1/t^{\alpha}\right)}{1+\exp\left\{b\left[log(t)-log(e)\right]\right\}}$$

UCRS.4b; α=0.5

UCRS.4c; α=0.25

- Five parameter Cedergreen-Ritz-Streibig modified log-logistic functions:

CRS.5a; α=1 $$MR = c + \frac{d - c + f\,exp\left(-1/t^{\alpha}\right)}{1 + \exp\left\{b\left[log\left(t\right) - log\left(e\right)\right]\right\}}$$

CRS.5b; α=0.5

CRS.5c; α=0.25

- Five parameter Cedergreen-Ritz-Streibig modified log-logistic functions for describing u-shaped hormesis:

UCRS.5a; α=1 $$MR = c + d - \frac{d - c + f\,exp\left(-1/t^{\alpha}\right)}{1 + \exp\left\{b\left[log\left(t\right) - log\left(e\right)\right]\right\}}$$

UCRS.5b; α=0.5

UCRS.5c; α=0.25

- Six parameter Cedergreen-Ritz-Streibig modified log-logistic function:

CRS.6: $$MR = c + \frac{d - c + f\,exp\left(-1/t^{\alpha}\right)}{1 + exp\left\{b\left[log\left(t\right) - log\left(e\right)\right]\right\}}$$

- Logistic functions:

L3 $$MR = \frac{d}{1 + exp\left\{b\left[log\left(t\right) - log\left(e\right)\right]\right\}}$$

L4 $$MR = c + \frac{d - c}{1 + exp\left\{b\left[log\left(t\right) - log\left(e\right)\right]\right\}}$$

L5 $$MR = c + \frac{d - c}{1 + exp\left\{b\left[log\left(t\right) - log\left(e\right)\right]\right\}^{f}}$$

- Exponential decay functions:

EXD.2 $$MR = a\left(1+b\right)^{t}$$

EXD.3 $$MR = c + \left(d - c\right) exp\left(-t / e\right)$$

- Gompertz growth model:

G.4: $$MR = c + \left(d - c\right) exp - exp\left\{b\left[log\left(t\right) - e\right]\right\}$$

- Two parameter log-logistic function:

LL.2 $$MR = \frac{1}{1 + \exp\left\{b\left[log\left(t\right) - log\left(e\right)\right]\right\}}$$

in another form $$MR = \frac{1}{1 + \exp\left\{b\left[log\left(t\right) - e\right]\right\}}$$

- Three parameter log-logistic function:

LL.3 $$MR = \frac{d}{1 + \exp\left\{b\left[log\left(t\right) - log\left(e\right)\right]\right\}}$$

in another form $$MR = \frac{d}{1 + \exp\left\{b\left[log\left(t\right) - e\right]\right\}}$$

- Three parameter log-logistic function where the upper limit is equal to 1:

LL.3u $$MR = c + \frac{1 - c}{1 + \exp\left\{b\left[log\left(t\right) - log\left(e\right)\right]\right\}}$$

in another form $$MR = c + \frac{1 - c}{1 + \exp\left\{b\left[log\left(t\right) - e\right]\right\}}$$

- Four parameter log-logistic function:

LL.4 $$MR = c + \frac{d-c}{1+\exp\left\{b\left[log(t)-log(e)\right]\right\}}$$

in another form $$MR = c + \frac{d-c}{1+\exp\left\{b\left[log(t)-e\right]\right\}}$$

- Five parameter log-logistic function:

LL.5 $$MR = c + \frac{d-c}{1+\exp\left\{b\left[log(t)-log(e)\right]\right\}^{f}}$$

in another form $$MR = c + \frac{d-c}{1+\exp\left\{b\left[log(t)-e\right]\right\}^{f}}$$

- Log normal funtions:

LN.2 $$MR = \frac{1}{t\sigma\sqrt{2\pi}}exp\left[-\frac{\left\{ln(t)-\mu\right\}^2}{2\sigma^2}\right]$$

LN.3 $$MR = \frac{1}{(t-\gamma)\sigma\sqrt{2\pi}}exp\left\{-\frac{\left[ln(t-\gamma)-\mu\right]^2}{2\sigma^2}\right\}$$

LN.3u (for σ=1) $$MR = \frac{1}{(t-\gamma)\ \sqrt{2\pi}}exp\left\{-\frac{\left[ln(t-\gamma)-\mu\right]^2}{2}\right\}$$

LN.4 $$MR = \frac{1}{\left(\frac{t-\beta}{\alpha-t}\right)\sigma\sqrt{2\pi}}exp\left\{-\frac{\left[ln\left(\frac{t-\beta}{\alpha-t}\right)-\mu\right]^2}{2\sigma^2}\right\}$$

- Two parameter Weibull function:

W1.2 $$MR = exp - exp\left\{b\left[log(t)-e\right]\right\}$$

W2.2 $$MR = \left(\frac{\beta}{\alpha}\right)\left(\frac{t}{\alpha}\right)^{\beta-1} exp\left[-\left(\frac{t}{\alpha}\right)^{\beta}\right]$$

- Three parameter Weibull function:

W1.3 $$MR = d\, exp - exp\left\{b\left[log\left(t\right) - e\right]\right\}$$

W2.3 $$MR = \frac{\alpha}{\beta}\left(\frac{t-\mu}{\beta}\right)^{\alpha-1} exp\left[-\left(\frac{t-\mu}{\beta}\right)^{\alpha}\right]$$

- Four parameter Weibull function:

W1.4 $$MR = c + \left(d - c\right)\mathrm{exp} - exp\left\{b\left[log\left(t\right) - log\left(e\right)\right]\right\}$$

in another form: $$MR = c + \left(d - c\right)1 - \mathrm{exp} - exp\left\{b\left[log\left(t\right) - log\left(e\right)\right]\right\}$$

W2.4 $$MR = \frac{k}{\vartheta}\left(\frac{t-\alpha}{2\beta\vartheta}\right)^{k-1} t^{-1} exp\left[-\left(\frac{t-\alpha}{2\beta\vartheta}\right)^{k}\right]$$

3. Statistical Analysis for Determination of Appropriate Models

In order to find best suitable model to explain drying behaviour of any product with different drying methods or different conditions, statistical methoods were generally used. The main methods used for drying studies in the literatures were given below.

Coefficient of determination, $\boldsymbol{R^2}$, is used in the context of statistical models whose main purpose is the prediction of future outcomes on the basis of other related information. It is the proportion of variability in a data set that is accounted for by the statistical model. It provides a measure of how well future outcomes are likely to be predicted by the model. The coefficient of determination is not likely to be 0 or 1, but rather somewhere in between these limits. The closer it is to 1, the greater relationship exists between experimental and predicted values (Neter et al., 1990). This value is used for the quantative comparison criteria and shows the level of agreement between measured and predicted values (Chen and Wu, 2001; Hossain et al., 2007). It is sometimes called as correlation coefficient (Akpinar, 2006a; Gunhan et al., 2005; Sobukola et al., 2008), coefficient of correlation (Dandamrongrak et al., 2002), r-square (Jazini and Hatamipour, 2010) or determination coefficient (Vega-Galvez et al., 2011). Although there are several different definitions of $\boldsymbol{R^2}$, it can be calculated by;

$$R^2 = 1 - \frac{Residual\ SS}{Corrected\ total\ SS}$$

Coefficient of correlation, $\boldsymbol{r}$, is the square root of $\boldsymbol{R^2}$ (Neter et al., 1990). This is a measure of the correlation (linear dependence) between two variables, giving a value between +1 and −1 inclusive. It is widely used in the sciences as a measure of the strength of linear dependence between two variables. It is called as correlation coefficient (Magalhaes and Pinho, 2008; Erbay and Icier, 2009), coefficient of correlation (Chin et al., 2009; Hacihafizoglu et al., 2008) or correlation index (Sander and Kardum, 2009) and given as;

$$r = \frac{\sum_{i=1}^{N}\left(MR_{exp,i} - MR_{exp,ave}\right)\left(MR_{pre,i} - MR_{pre,ave}\right)}{\sqrt{\sum_{i=1}^{N}\left(MR_{exp} - MR_{exp,ave}\right)^2 \sum_{i=1}^{n}\left(MR_{pre} - MR_{pre,ave}\right)^2}} -$$

Reduced chi-square, χ^2, is the mean square of the deviations between experimental and predicted values for the models and used to evaluate the fitting agreement of each model. The lower the values of χ^2, the better the goodness of the fit (Yang et al., 2007; Fumagalli and Freire, 2007; Menges and Ertekin, 2006a; Ozbek and Dadali, 2007). It is called as mean squared deviation (Cihan et al., 2007; Celen et al., 2010), reduced mean square of deviation (Demir et al.,

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2007), mean square of deviation (Jain and Pathare, 2004; Doymaz, 2004b) and standard deviation (Midilli et al., 2002) and could be calculated as follows;

$$\chi^2 = \frac{\sum_{i=1}^{N}\left(MR_{exp,i} - MR_{pre,i}\right)^2}{N-n}$$

Mean relative percentage error, *P*, is the average of the relative percent difference between the experimental and predicted values. It compares the absolute difference between the predicted moisture content with the experimental moisture content throughout drying process. It is used to evaluate the predictive precision of the models. The values of P less than 5% indicate an excellent fit, less than 10% a good fit, while values greater than 10% are indicative of a poor fit (Diamente et al., 2010; Sacilik and Elicin, 2006; Doymaz, 2009b). It is called in different terms as average percent error (Kumar et al., 2006), percent mean relative error (Vega-Galvez et al., 2008b), relative percent deviation (Mota et al., 2010), mean relative percent deviation (Lee and Kim, 2009; Sacilik and Unal, 2005; Kailappan and Kaleemullah, 2006), mean relative deviation modulus (Usub et al., 2010; Mundada et al., 2010), relative percentage error (Roberts et al., 2008), percentage error (Wang et al., 2009), mean relative percentage error (Doymaz, 2009b; Sacilik et al., 2006), mean relative percent error (Doymaz, 2009a; 2010; 2011b), relative percent error (Fang et al., 2009; Shittu and Raji, 2011), percent mean relative deviation modulus (Zenoozian et al., 2008), mean relative percent deviation modulus (Purkayastha et al., 2011), relative error (Dissa et al., 2011), mean relative deviation (Chowdhury et al., 2011), mean relative error (Jazini and Hatamipour, 2010), relative deviation percent (Jena and Das, 2007), average percent difference (Singh et al., 2006) and could be calculated as follows;

$$P = \frac{100}{N}\sum_{i=1}^{N}\left[\frac{\left|MR_{exp,i} - MR_{pre,i}\right|}{MR_{exp,i}}\right]$$

Root-mean-square deviation, *RMSD*, or **root-mean-square error, *RMSE*,** is a frequently used measure of the differences between values predicted by a model or an estimator and the values actually observed from the thing being modeled or estimated. *RMSD* is a good measure of accuracy and serves to aggregate the residuals into a single measure of predictive power. It is required to reach zero and can be calculated as (Wang et al., 2007a; Togrul, 2006; Doymaz, 2007b; 2007c; Menges and Ertekin, 2006b; Changrue et al., 2008);

$$RMSE = \left\{\frac{1}{N}\sum_{i=1}^{N}\left(MR_{exp,i} - MR_{pre,i}\right)^2\right\}^{\frac{1}{2}}$$

It is called as root mean square analysis (Akbulut and Durmus, 2009), standard deviation (Cihan et al., 2007; Hacihafizoglu et al., 2008), root mean sum error (Vega-Galvez et al., 2009b), standard error (Jain and Pathare, 2004), root mean square difference (Kumar et al., 2006).

There is also another form of root mean square deviation (Contreras et al., 2008);

$$RMSD = \frac{1}{N}\sqrt{\sum_{i=1}^{N}\left(MR_{exp,i} - MR_{pre,i}\right)^2}$$

Modeling efficiency, EF, gives the fitting ability of the model and its highest value is 1 (Menges and Ertekin, 2006c; Karabulut et al., 2007; Pardeshi et al., 2009) and could be calculated as follows;

$$EF = \frac{\sum_{i=1}^{N}\left(MR_{exp,i} - MR_{exp,ave}\right)^2 - \sum_{i=1}^{N}\left(MR_{pre,i} - MR_{exp,i}\right)^2}{\sum_{i=1}^{N}\left(MR_{exp,i} - MR_{exp,ave}\right)^2}$$

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Residuals, is the measure of the deviation of a sample from its "theoretical value". The residuals are defined as the difference between the experimental and predicted data (Dadali et al., 2007b; Demirhan and Ozbek, 2010a; 2010b). It is called as residual sum of squares (Al-Muhtaseb et al., 2010; Arabhossaini et al., 2009; Doymaz, 2011c) or sum square error (Liu et al., 2009) and defined as;

$$Residuals = \sum_{i=1}^{N}\left(MR_{exp} - MR_{pre}\right)^2$$

It is also calculated as follows and called as sum of residuals (Celma et al., 2007; 2009; Madhiyanon et al., 2009) or residuals (Akgun and Doymaz, 2005);

$$Residuals = \sum_{i=1}^{N}\left(MR_{exp,i} - MR_{pre,i}\right)$$

Mean absolute error, *MAE*, is a quantity used to measure how close forecasts or predictions to the eventual outcomes. The mean absolute error is given by (Tripathy and Kumar, 2008; Mota et al., 2010);

$$MAE = \frac{1}{N}\sum_{i=1}^{N}\left|MR_{exp,i} - MR_{pre,i}\right|$$

Mean bias error, *MBE*, is a measurement error that remains constant in magnitute for all observation; a kind of systematical error (Togrul, 2006; Faustino et al., 2007; Goyal et al., 2007);

$$MBE = \frac{1}{N}\sum_{i=1}^{N}\left(MR_{pre,i} - MR_{exp,i}\right)$$

Mean squared error, *MSE*, is one of many ways to quantify the difference between values implied by an estimator and the true values of the quantity being estimated. *MSE* is a risk function, corresponding to the expected value of the squared error loss or quadratic loss. *MSE*

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measures the average of the squares of the "errors." The error is the amount by which the value implied by the estimator differs from the quantity to be estimated. The difference occurs because of randomness or because the estimator does not account for information that could produce a more accurate estimate.

The *MSE* is the second moment (about the origin) of the error, and thus incorporates both the variance of the estimator and its bias. For an unbiased estimator, the *MSE* is the variance of the estimator. Like the variance, *MSE* has the same units of measurement as the square of the quantity being estimated. In an analogy to standard deviation, taking the square root of *MSE* yields the root mean square error or root mean square deviation (*RMSE* or *RMSD*), which has the same units as the quantity being estimated; for an unbiased estimator, the *RMSE* is the square root of the variance, known as the standard deviation. It can be calculated as follows (Therdthai et al., 2011);

$$MSE = \frac{1}{N}\sum_{i=1}^{N}\left(MR_{exp,i} - MR_{pre,i}\right)^2$$

It is called as sum square error (Vega-Galvez et al., 2009c; Mota et al., 2010; Doymaz, 2004c) or reduced sum square error (Erenturk et al., 2004; Jazini and Hatamipour, 2010).

Standard Deviation, σ, shows how much variation or "dispersion" exists from the average (mean, or expected value). A low standard deviation indicates that the data points tend to be very close to the mean, whereas high standard deviation indicates that the data points are spread out over a large range of values.

The standard deviation of a random variable, statistical population, data set or probability distribution is the square root of its variance. It is algebraically simpler though practically less robust than the average absolute deviation. A useful property of standard deviation is that, unlike variance, it is expressed in the same units as the data. It could be calculated as follows (Celen et al., 2010);

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(MR_{exp,i} - MR_{exp,ave,i}\right)}$$

Standard error, *SE*, is the standard deviation of the sampling distribution of a statistic. This procedure minimizes the sum of squares of the difference between the predicted and experimental moisture content with below equation (Tripathy and Kumar, 2008; Mota et al., 2010; Baini and Langrish, 2007);

$$SE = \sqrt{\frac{\sum_{i=1}^{N}\left(MR_{exp,i} - MR_{pre,i}\right)^2}{N-1}}$$

There is also another equation for standard error (Nourhene et al., 2008), it is also called as standard error of estimate (Abalone et al., 2006; Chowdhury et al., 2011; Xanthopoulos et al., 2007a) or standard error coefficient (Djendaubi et al., 2009);

$$SE = \sqrt{\frac{\sum_{i=1}^{N}\left(MR_{exp} - MR_{pre}\right)^2}{N-n}}$$

Another equation for standard error of estimate is given as (Arabhosseini et al., 2009; Kailappan and Kaleemullah, 2006);

$$SE = \sqrt{\frac{\sum_{i=1}^{n}\left(MR_{exp,i} - MR_{pre,i}\right)^2}{d.f.}}$$

There is also another criteria that means standard deviation (Chowdhury et al., 2011);

$$SE = \frac{1}{N}\left[\frac{\sum_{i=1}^{N}\left(MR_{pre} - MR_{exp}\right)^2}{MR_{exp}}\right]$$

***t*-Statistic, *t-stat*,** is used to determine whether or not the equation estimates are statistically significant, i.e. not significantly different from their actual counterparts, at a particular confidence level. It could be calculated by (Gunhan et al., 2005; Kaleta and Gornicki, 2010, Hayaloglu et al., 2007);

$$t - stat = \left[\frac{(n-1)MBE^2}{RMSE^2 - MBE^2}\right]^{1/2}$$

The *t*-value produced by this equation must be smaller than the value for that confidence level given in standard statistical tables.

Mean absolute percentage error, *MAPE*, also known as mean absolute percentage deviation (*MAPD*), is a measure of accuracy of a method for constructing fitted time series values in statistics, specifically in trend estimation. It usually expresses accuracy as a percentage, and is defined by the formula (Dandamrongrak et al., 2002):

$$MAPE = \frac{100}{N}\sum_{i=1}^{N}\left|\frac{MR_{exp} - MR_{pre}}{MR_{exp}}\right|$$

Although the concept of *MAPE* sounds very simple and convincing, it has two major drawbacks in practical application;

- If there are zero values (which sometimes happens for example in demand series), there will be a division by zero,
- When having a perfect fit, *MAPE* is zero. But in regard to its upper level, the *MAPE* has no restriction.

When calculating the average *MAPE* for a number of time series there might be a problem: a few of the series that have a very high *MAPE* might distort a comparison between the average *MAPE* of time series fitted with one method compared to the average *MAPE* when using another method. In order to avoid this problem other measures have been defined, for example the *sMAPE* (symmetrical *MAPE*), weighted absolute percentage error (WAPE), real aggregated percentage error (*RAPE*) or a relative measure of accuracy (*ROMA*).

Information Criteria, *AIC* and *BIC*, The overall predictive power and goodness of fit for different nonlinear functions can be evaluated using predictive densities. The observed values, y_j, are compared with their predictions. There are a number of analytical criteria to evaluate overall goodness of fit of different nonlinear models. These criteria are so-called Information Criteria based on likelihood estimations (Oman, 1991; Wolfinger, 1993) and based on the recommendation of choosing the model for which the likelihood of the data minus a penalty for the model dimension obtains the maximum value. One of the most frequently used criteria is the Akaike Information Criterion (AIC) (Akaike, 1974) given as follows;

$$\mathrm{AIC} = -2l_i + 2k_i$$

where l_i is the maximum value of the log likelihood of the i_{th} model and k_i is the number of the parameters of the i_{th} model. If the two models favor the data equally well using AIC, the most parsimonious should be chosen. The Bayesian Information Criterion (Schwarz, 1978), differing from AIC only in the fact that the dimension is multiplied by 0.5log(n), recommends choosing the model that maximizes the following expression;

$$\mathrm{BIC} = -2l_i + k_i \log(n)$$

This implies that the AIC leans more towards lower dimensional models and these criteria differ markedly from each other for large number of observations. Information Criteria such as AIC and BIC are increasingly being used to address model selection problems (Acquah, 2010). The respective values of these two criteria are compared across various models with the rule that smaller is better (i.e., the model with the smallest criterion value is the best model for the data). The two criteria may not necessarily agree on the best model because the BIC has a stronger penalty, which is a function of the number of unknown parameters and sample size. Many Monte-Carlo ismulations indicate that, the BIC and AIC selection criteria need to be used together (Yesilova et al., 2010). Since our objective is to choose the most parsimonious model, we will rely more on the BIC than the AIC criterion.

In these modeling studies, different drying parameters affected the moisture ratio in different drying methods. In convective drying process; the effect of drying air temperature was shown for barley (Bruce, 1985; Boyce, 1965; Sun and Woods, 1994), wheat and fresh ryegrass (O'Callaghan et al., 1971), sorghum (Paulsen and Thompson, 1973), lentil (Tang et al., 1989), soybeans (Overhults et al., 1973), alfalfa (Rowe and Gunkel, 1972), corn (Thompson et al., 1968), apple pomace (Wang et al., 2007), roselle (Suherman et al., 2012), kiwi (Mohammadi et al., 2008) and finger millet (Radhika et al., 2011). The effect of drying air relative humidity on model was investigated for bluestem grass seed (Farmer et al., 1983) and in-shell pecans (Chhinnan, 1984). The effect of drying air velocity for olive leaves was investigated (Erbay and Icier, 2008b). The effect of tempering time for rough rice (Cihan et al., 2007) were also examined. The effects of two parameters such as drying air temperature and relative humidity were investigated for rough rice (Agrawal and Singh, 1977; Byler and Brook, 1984; Basunia and

Abe, 1998), rapeseed (Correa et al., 1999), soybeans and white beans (Hutchinson and Otten, 1982), buckwheat (Tabatabaee et al., 2004), barley (Jayas and Sokhansanj, 1989), hazelnut (Lopez et al., 1998), longan (Janjai et al., 2011a), corn (Westerman et al., 1973), rice (Wang and Singh, 1978), bay leaves (Gunhan et al., 2005), litchi (Janjai et al., 2011b) and rapeseed (Duc et al., 2011) and also drying air temperature and absolute humidity for rice (Chen, 1996). There are also many studies for the effect of drying air temperature and velocity on eggplant (Akpinar and Bicer, 2005), marigold flowers (Buser et al., 1999), quercus (Tahmasebi et al., 2011), sour cherry (Aghbashlo et al., 2010), pistachio nuts (Kashaninejad et al., 2007), onion (Sawhney et al., 1999), rough rice (Hacihafizoglu et al., 2008), black tea (Panchariya et al., 2002), apricot (Bozkir, 2006) and barberry (Aghbashio et al., 2009). Another two parameters effecting the drying model are drying air temperature and initial moisture content of the product and examined for sunflower (Li et al., 1987), walnuts (Anigbankpu et al., 1980), alfalfa (Patil, 1995), carthamus tinctorius L. seeds (Tironi et al., 2004), corn (Hustrulid and Flikke, 1959) and ear corn (Friant et al., 2003; Sharaf-Eldeen et al., 1980). The effects of drying air temperature and the slice thickness were studied for apple (Sacilik and Elicin, 2006; Meisami-Asl et al., 2010), coconut (Madamba, 2003), flax fiber (Ghazanfari et al., 2006b). In three parameters, drying air temperature, relative humidity and velocity effects shown in the models for green chilli (Hossain and Bala, 2002), jackfruit leather (Choudhury et al., 2011), red chilli (Hossain et al, 2007), rough rice (Iguaz et al., 2003) and maize (Shijun and Xuejun, 2011). The effects of drying air temperature, relative humidity and air mass flow rate for silkworm pupae (Usub et al., 2010). In drying models, the effects of drying air temperature, velocity and humidity ratio were investigated for rosehip (Erenturk et al., 2004), drying air temperature, velocity and absolute humidity for bagasse (Vijayaraj et al., 2007), drying air temperature, relative humidity and initial moisture content for peanut pods (Kulasiri et al., 1989), rice (Wongwises and Thongprasert, 2000), soybean (White et al., 1978 and 1981), amaranth seed (Abolone et al., 2006), drying air temperature, relative humidity, initial and equilibrium moisture content for wheat (Sinico et al., 1995), drying air temperature, velocity and initial moisture content for rapeseed (Patil and Ward, 1989). The effects of drying air temperature, velocity and sample area were also investigated for apple (Akpinar and Bicer, 2003), potato, pumpkin and apple (Akpinar, 2006b). In another study, the effects of initial moisture content, slice thickness and material load were examined for red beet (Kaleta and Gornicki, 2010). The effects of drying air temperature, velocity, relative humidity and initial moisture content for corn were also investigated (Misra and Brooker, 1980). The effects of drying air temperature, velocity, relative humidity, equilibrium moisture content and final moisture content for peanut were examined (Yang et al., 2007).

In solar drying, the effect of drying air temperature for preackly pear cladode (Lahsasni et al., 2004c), prickly pear peel (Lahsasni et al., 2004b), prickly pear fruit (Lahsasni et al., 2004a), pistachio (Midilli and Kucuk, 2003), citrus aurantium and gelidium sesquipedale (Ait Mohamed et al., 2005 and 2008), parsley (Akpinar et al., 2006), initial moisture content for banana, mango and cassava (Koua et al., 2009), drying air velocity and temperature increasement for seeded grape (Cakmak and Yildiz, 2011), drying air temperature and relative humidity for longan (Janjai et al., 2009), rough rice (Basunia and Abe, 2001), tomato (Sacilik et al., 2006), drying air temperature, relative humidity and velocity for cuminum (Zomorodian and Moradi, 2010), apricot (Togrul and Pehlivan, 2002), drying air temperature, velocity and rotation speed of column for apricot (Akpinar et al., 2004), In infrared drying process the effects of different parameters on thin layer drying model were also investigated and the effect of drying air temperature for grape by products (Celma et al., 2009a), apple (Togrul, 2005), tomato by products (Celma et al., 2009b), carrot (Togrul, 2006) and olive husk (Celma et al., 2008), drying air temperature and velocity for onion (Sharma et al., 2005), drying air temperature, velocity and infrared intensity for onion (Jain and Pathare, 2004), the effect of infrared peak wavelength and initial moisture content for paddy (Laohavanich and Wongpichet, 2008), infrared radiation intensity, slice thickness, drying air velocity and relative humidity for onion (Wang, 2002), drying air temperature, inlet air temperature, slice thickness, drying air velocity and drying time for onion (Kumar et al., 2006) were determined.

The effects of drying air temperature and velocity on mistletoe were determined during convective and UV combined convective drying process (Kose and Erenturk, 2010).

In microwave drying, the effects of microwave output power for organic ginger, manga ginger, zingiber officianale and curcuma mangga (Ganesapillai et al., 2011), jujube (Wang et al., 2009), apple pomace (Wang et al., 2007b), drying air temperature for spinach (Karaaslan and Tuncer, 2008), material load for parsley (Soysal et al., 2006).

In heat pump drying, the effect of drying air temperature and velocity for kiwi, avacado and banana (Ceylan et al., 2007), yacon slices (Shi et al., 2013), drying air temperature, velocity and absolute humidity for fig (Xanthopoulas et al., 2007b), drying air temperature, velocity and type of the product for tomatoes (Queiroz et al., 2004).

In vacuum drying, the effect of temperature were examined for ginger slices (Thorat et al., 2012).

In microwave vacuum drying, the effects of microwave power level and vacuum pressure were investigated for apple, kiwi and pear (Kiranoudis et al., 1997).

In vacuum heat pump drying process, the effect of temperature for chilli, lemon grass, kaffir lime leaf and galangal slice (Artnaseaw et al., 2010b), the effect of temperature and vacuum pressure for mushroom and chilli (Artnaseaw et al., 2010a).

In fluidised bed drying, the effects of drying air temperature and specific airflow rate for soybean (Soponronnarit et al., 2001), drying air temperature for coconut (Madhiyanon et al, 2009) were shown.

The effects of drying air temperature, relative humidity and velocity were determined for cork stoppers in spouted bed drying (Magalhaes and Pinho, 2008).

In microwave vibro fluidised bed drying, the effect of drying air temperature was investigated for rice (Sripinyowanich and Noomhorm, 2011).

The effects of drying air temperature and relative humidity on apricot, grape, peach, plum and fig (Togrul and Pehlivan, 2004), and the effect of drying air temperature on pistachio (Midilli et al., 2002) in natural sun drying process were investigated.

The effects of these parameters were shown in the drying models as simple linear, power, exponential, arrhenius, logaritmic, polynomial, inverse polinomial, rational type, multi linear or in another forms.

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REFERENCES

Abalone, R., Gaston, A., Cassinera, A., and Lara, M.A. (2006). Thin layer drying of amaranth seeds. *Biosystems Engineering* **93** : 179–188.

Acquah, H.D.G. (2010). Comparison of Akaike information criterion (AIC) and Bayesian information criterion (BIC) in selection of an asymetric price relationship. *Journal of Development and Agricultural Economics* **2** : 1-6.

Ademiluyi, T., Oboho, E.O., and Owudogu, M. (2008). Investigation into the thin layer drying models of Nigerian popcorn varieties. *Leonardo Electronic Journal of Practices and Technologies* **13** : 47-62.

Aghbashlo, A., Kianmehr, M.H., and Akhijahani, H.S. (2009). Evaluation of thin layer drying models for describing drying kinetics of barberries. *Journal of Food Process Engineering* **32** : 278-293.

Aghbashlo, M., Kianmehr, M.H., and Hassan-Beygi S.R. (2010). Drying And Rehydration Characteristics Of Sour Cherry (*Prunus Cerasus* L.). *Journal of Food Processing and Preservation* **34** : 351–365.

Aghbashlo, M., Kianmehr, M.H., and Samimi-Akhijahani H. (2007). Evaluation of thin-layer drying models for describing drying kinetics of barberries (*Barberries Vulgaris*). *Journal of Food Process Engineering* **32** : 278-293.

Aghbashlo, M., Kianmehr, M.H., Khani, S., and Ghasemi, M. (2009). Mathematical modelling of thin-layer drying of carrot. *Int. Agrophysics* **23** : 313-317.

Agrawal, Y.C., and Singh, R.D. (1977). Thin layer drying studies for short graib rice. ASAE Paper No: 77-3531.

Ait Mohamed, L., Kane, C.S.E., Kouhila, M., Jamali, A., Mahrouz, M., and Kechaou, N. (2008). Thin layer modeling of gelidium sesquipedale solar drying process. *Energy Conversion and Management* **49** : 940-946.

Ait Mohamed, L., Kouhila M., Jamali, A., Lahsasni, S., Kechaou, N., and Mahrouz, M. (2005). Single layer solar drying behavior of citrus aurantium leaves under forced convection. *Energy Conversion and Management* **46** : 1473-1483.

Akaike, H. (1974). A new look at the statistical model identification. *IEEE Trans. Automat. Control* **19** : 716-723.

Akbulut, A. and Durmus, A. (2009). Thin layer solar drying and mathematical modeling of mulberry. *Int. J. Energy Res.* **33** : 687–695.

Akgun, N.A., and Doymaz, I. (2005). Modelling of olive cake thin-layer drying process. *Journal of Food Engineering* **68** : 455–461.

Akpinar, E. K., Bicer, Y., 2005. Modelling Of The Drying Of Eggplants In Thin-Layers. *International Journal of Food Science and Technology* **40**, 273–281.

Akpinar, E.K. (2006a). Mathematical modelling of thin layer drying process under open sun of some aromatic plants. *Journal of Food Engineering* **77** : 864-870.

Akpinar, E.K. (2006b). Determination of suitable thin layer drying curve model for some vegetables and fruits. *Journal of Food Engineering* **73** : 75-84.

Akpinar, E.K. (2011). Drying of parsley leaves in a solar dryer and under open sun: modeling, energy and exergy aspects. *Journal of Food Process Engineering* **34** : 27-48.

Akpinar, E.K., and Bicer, Y. (2003). Modeling and experimental study on drying of apple slices in a convective cyclone dryer. *Journal of Food Process Engineering* **26** : 515-541.

Akpinar, E.K., Bicer, Y., and Yildiz, C. (2003). Thin layer drying of red pepper. *Journal of Food Engineering* **59** : 99-104.

Akpinar, E.K., Sarsilmaz, C., and Yildiz, C. (2004). Mathematical modeling of a thin layer drying of apricots in a solar energized rotary dryer. *International Journal of Energy Research* **28** : 739-752.

Akpinar, E.K.,; Bicer, Y., and Cetinkaya, F. (2006). Modelling of thin layer drying of parsley leaves in a convective dryer and under open sun. *Journal of Food Engineering* 75: 308–315.

Aktas, T., and Polat, R. (2007). Changes in the drying characteristics and water activity values of selected pistachio cultivars during hot air drying. *Journal of Food Process Engineering* **30** : 607-624.

Alibas, I. (2012). Microwave drying of grapevine (vitis vinifera l.) Leaves and determination of some quality parameters. *Journal of Agricultural Sciences* **18** : 43-53.

Al-Mahasneh, M.A., Rababah, T.M., and Al-Shbool M.A. (2007). Thin-layer drying kinetics of sesame hulls under forced convection and open sun drying. *Journal of Food Process Engineering* **30** : 324-337.

Al-Muhtaseb, A.H., Al-Harahsheh, M., Hararah, M., and Magee, T.R.A. (2010). Drying characteristics and quality change of unutilized-protein rich-tomato pomace with and without osmotic pre-treatment. *Industrial Crops And Products* **31** : 171–177.

 ACCEPTED MANUSCRIPT

Anigbankpu, C.S., Rumsey, T.R., and Thompson, J.F. (1980). Thin layer drying and equilibrium moisture content equations for Ashley walnuts. ASAE Paper No : 80- 6507.

Arabhosseini, A., Huisman, W., Van Boxtel, A., and Müller, J. (2009). Modeling of thin layer drying of tarragon (artemisia dracunculus l.). *Industrial Crops And Products* **29** : 53–59.

Arslan, D., and Ozcan, M.M. (2012). Evaluation of drying methods with respect to drying kinetics, mineral content, and color characteristics of savory leaves. *Food Bioprocess Technol.* **5** : 983-991.

Artnaseaw, A., Theerakulpisut, S., and Benjapiyaporn, C. (2010a). Drying characteristics of Shiitake mushroom and Jinda chili during vacuum heat pump drying. *Food and Bioproducts Processing* **88** : 105-114.

Artnaseaw, A., Theerakulpisut, S., and Benjapiyaporn, C. (2010b). Thin layer modeling of Tom Yum herbs in vacuum heat pump dryer. *Food Sci. Tench. Int.* **1** : 1-12.

ASAE (2001). Thin-Layer Drying of Agricultural Crops . ANSI/ASAE S448.1 JUL2001 (R2006).

Babalis, S.J., Papanicolaou, E., and Kyriakis, N. (2006). Evaluation of thin-layer drying models for describing drying kinetics of figs (Ficus carica). *Journal of Food Engineering* **75** : 205-214.

Baini, R., and Langrish, T.A.G. (2007). Choosing an appropriate drying model for intermittent and continuous drying of bananas. *Journal of Food Engineering* **79** : 330-343.

Bal, L.M., Kar, A., and Satya, S. (2010). Drying kinetics and effective moisture diffusivity of bamboo shoot slices undergoing microwave drying. *International Journal of Food Science and Technology* **45** : 2321-2328.

 ACCEPTED MANUSCRIPT

Barrozo, M.A.S., Sartori, D.J.M., and Freire, J.T. (2004). A study of the statistical discrimination of the drying kinetics equations. *Food and Bioproducts Processing* **82** : 219-225.

Basunia, M.A., and Abe, T. (1998). Thin layer drying characteristics of rough rice at low and high temperatures. *Drying Technology* **16** : 579-595.

Basunia, M.A., and Abe, T. (2001). Thin layer solar drying characteristics of rough rice under natural convection. *Journal of Food Engineering* **47** : 295-301.

Boyce, D.S. (1965). Grain moisture and temperature changes with position and time during through drying. Journal of Agricultural Engineering Research 10 : 333-341.

Bozkir, O. (2006). Thin layer drying and mathematical modeling for washed dry apricots. *Journal of Food Engineering* **77** : 146-151.

Brooker, D.B., Bakker Arkema, F.W., and Hall, C.W. 1974. Drying Cereal Grains. AVI Publishing Company.

Bruce, D.M. (1985). Exposed layer barley drying, three models fitted to new data up to 150 ^{o}C. *Journal of Agricultural Engineering Research* **32** : 337-347.

Buser, M.D., Stone, M.L., Brusewitz, G.H., Maness, N.O., Whitelock, D.P. (1999). Thin layer drying of marigold flowers and flower components for petal removal. *Transactions of the ASAE* **42** : 1367-1373.

Byler, R.K., and Brook, R.C. (1984). Thin layer model, temperature and relative humidity variable. ASAE Paper No : 84-3525.

Cakmak, G., and Yildiz, C. (2011). The drying kinetics of seeded grape in solar dryer with PCM-based solar integrated collector. *Food and Bioproducts Processing* **89** : 103-108.

Celen, S., kahveci, K., Akyol, U., and Haksever, A. (2010). Drying behavior of cultured mushrooms. *Journal of Food Processing and Preservation* **34** : 27–42.

Celma, A.R., Cuadros, F., and Lopez-Rodriguez, F. (2009b). Characterisation of industrial tomato by-products from infrared drying process. Food and Bioproducts Processing 87 : 282-291.

Celma, A.R., Lopez-Rodriguez, F., and Blazquez, F.C. (2009a). Experimental modeling of infrared drying of industrial grape by-products. *Food and Bioproducts Processing* **87** : 247-253.

Celma, A.R., Rojas, S., and Lopez-Rodriguez, F. (2008). Mathematical modeling of thin layer infrared drying of wet olive husk. *Chemical Engineering and Processing* **47** : 1810-1818.

Celma, A.R., Rojas, S., Lopez, F.,Montero, I., and Miranda, T. (2007). Thin-layer drying behaviour of sludge of olive oil extraction. *Journal of Food Engineering* **80** : 1261–1271.

Ceylan, I., Aktas, M., and Dogan, H. (2007). Mathematical modeling of drying characteristics of tropical fruits. *Applied Thermal Engineering* **27** : 1931-1936.

Changrue, V., Orsat, V., and Raghavan, G.S.V. (2008). Osmotically dehydrated microwave-vacuum drying of strawberries. *Journal of Food Processing And Preservation* **32** : 798–816.

Chayjan, R.A., Alizade, H.H.A., and Shadidi, B. 2012. Modeling of some pistachio drying characteristics in fix, semi fluid and fluid bed dryer. *CIGR Journal* **14** : 143-154.

Chen C.H.; Wu P.C.; 2001. Thin-layer drying model for rough rice with high moisture content. *Journal of Agricultural Engineering Research* **80** : 45-52.

Chen, Y.L. (1996). A thin layer drying equation for paddy rice in an intermittent drying pattern. *Journal of Agricultural Machinery* **5** : 55-64.

Chhinnan, M.S. (1984). Evaluation of selected mathematical models for describing thin layer drying of in shell pecans. *Transactions of the ASAE* **27** : 610-615.

Chin, S. K., Law, C.L., Supramaniam, C.V., and Cheng, P.G. (2009). Thin-layer drying characteristics and quality evaluation of air-dried ganoderma tsugae murrill. *Drying Technology* **27** : 975–984.

Chottanom, P., and Phoungchandang, S. (2005). The development of osmotically dehydrated mangoes using conventional drying and dehumidified drying. *Chemical Engineering Transactions* **6** : 897-902.

Choudhury, M.M.I., Bala, B.K., and Haque, M.A. (2011). Mathematical modeling of thin-layer drying of jackfruit leather. *Journal of Food Processing and Preservation* **35** : 797-805.

Cihan, A., Kahveci, K., and Hacihafizoglu, O. (2007). Modelling of intermittent drying of thin layer rough rice. *Journal of Food Engineering* **79** : 293–298

Contreras, C., Martin-Esparza, M.E., Chiralt, A., and Martinez-Navarrete, N. (2008). Influence of microwave application on convective drying: effects on drying kinetics, and optical and mechanical properties of apple and strawberry. *Journal of Food Engineering* **88** : 55–64.

Correa, P.C., Martins, J.H., and Christ, D. (1999). Thin layer drying rate and loss of viability modeling for rapeseed. *J. Agric. Engng. Res.* **74** : 33-39.

Corzo, O., Bracho, N., and Alvarez, C. (2010). Weibull model for thin-layer drying of mango slices at different maturity stages. *Journal of Food Processing and Preservation* **34** : 993–1008.

 ACCEPTED MANUSCRIPT

Corzo, O., Bracho, N., and Alvarez, C. (2011). Determination of suitable thin layer model for air drying of mango slices (mangifera indica l.) at different air temperatures and velocities. *Journal of Food Process Engineering* **34** : 332-350.

Crank, J. (1975). The mathematics of diffusion. 2nd edition,Clarendon Press, Oxford, Great Britain.

Dadalı, G., Apar, D.K., and Ozbek, B. (2007b). Microwave drying kinetics of okra. *Drying Technology* **25** : 917–924.

Dadali, G., Demirhan, E., and Ozbek, B. (2007a). Microwave heat treatment of spinach: Drying kinetics and effective moisture diffusivity. *Drying Technology* **25** : 1703-1712.

Dandamrongrak, R., Young, G., and Mason, R. (2002). Evaluation of various pre-treatments for the dehydration of banana and selection of suitable drying models. *Journal of Food Engineering* **55** : 139-146.

Daud,W.R.W.,Talib, M.Z.M., and HOOI, O.C. (2007). Characteristics of superheated steam through drying of kenaf fibers. The Proceedıngs of the 5th Asia-Pasific Drying Conference Vol.1 : 144-149.

Demir, V., Gunhan, T., and Yagcioglu, A.K. (2007). Mathematical modelling of convection drying of green table olives. *Biosystems Engineering* **98** : 47–53.

Demirhan, E., and Ozbek B. (2010b). Microwave-drying characteristics of basil. *Journal of Food Processing and Preservation* **34** : 476–494.

Demirhan, E., and Ozbek, B. (2010a). Drying kinetics and effective moisture diffusivity of purslane undergoing microwave heat treatment. *Korean J. Chem. Eng.* **27** : 1377-1383.

Demirhan, E., and Ozbek, B. (2011). Thin-layer drying characteristics and modeling of celery leaves undergoing microwave treatment. *Chemical Engineering Communications* **198** : 957-975.

Devahastin, S. (2000). Mujumdar's Practical Guide to Industrial Drying. Exergex Corporation, Canada.

Diamante, L.M., Ihns, R., Savage, G.P., and Vanhanen, L. (2010). A new mathematical model for thin layer drying of fruits. *International Journal of Food Science and Technol*ogy **45** : 1956–1962

Dissa, A.O., Desmorieux, H., and Bathiebo, J. (2008). Convective drying characteristics of Amelie mango (Mangifera Indica L. cv. 'Amelie') with correction for shrinkage. *Journal of Food Engineering* **88** : 429-437.

Dissa, O.A., Bathiebo, D.J., Desmorieux, H., Coulibaly, O., and Kouliati, J. (2011). Experimental characterisation and modelling of thin layer direct solar drying of Amelie and Brooks mangoes. *Energy* **36** : 2517-2527.

Djendoubi, N., Boudhrioua, N., Bonazzi, C., and Kechaou, N. (2009). Drying of sardine muscles: Experimental and mathematical investigations. *Food and bioproducts processing* **87** : 115–123

Doymaz, I. (2004a). Drying kinetics of white mulberry. *Journal of Food Engineering* **61** : 341-346.

Doymaz, I. (2004b). Effect of pre-treatments using potassium metabisulphide and alkaline ethyl oleate on the drying kinetics of apricots. *Biosystems Engineering* **89** : 281–287.

 ACCEPTED MANUSCRIPT

Doymaz, I. (2004c). Effect of dipping treatment on air drying of plums. *Journal of Food Engineering* **64** : 465-470.

Doymaz, I. (2005). Sun drying of figs: an experimental study. *Journal of Food Engineering* **71**, 403–407.

Doymaz, I. (2006). Drying kinetics of black grapes treated with different solutions. *Journal of Food Engineering* **76** : 212–217.

Doymaz, I. (2007a). Air-drying characteristics of tomatoes. *Journal of Food Engineering* **78** : 1291-1297.

Doymaz, I. (2007b). Influence of pretreatment solution on the drying of sour cherry. *Journal of Food Engineering* **78** : 591–596.

Doymaz, I. (2007c). The kinetics of forced convective air-drying of pumpkin slices. *Journal of Food Engineering* **79** : 243–248.

Doymaz, I. (2008a). Drying of leek slices using heated air. *Journal of Food Process Engineering* **31** : 721–737.

Doymaz, I. (2008b). Influence of blanching and slice thickness on drying characteristics of leek slices. *Chemical Engineering and Processing* **47** : 41-47.

Doymaz, I. (2009a). Mathematical modelling of thin-layer drying of kiwifruit slices. *Journal of Food Processing and Preservation* **33** : 145–160.

Doymaz, I. (2009b). An experimental study on drying of green apples. *Drying Technology* **27** : 478–485.

Doymaz, I. (2010). Effect of citric acid and blanching pre-treatments on drying and rehydration of Amasya red apples. *Food and Bioproducts Processing* **88** : 124–132.

Doymaz, I. (2011a). Drying of thyme and selection of a suitable thin layer drying model. *Journal of Food Processing and Preservation* **35** : 458-465.

Doymaz, I. (2011b). Drying of pomegranate arils and selection of a suitable drying model. *Food Biophysics* **6** 461-467.

Doymaz, I. (2011c). Drying of eggplant slices in thin layers at different air temperatures. *Journal of Food Processing and Preservation* **35** : 280-289.

Doymaz, I. (2012). Sun drying of seedless and seeded grapes. *Journal of Food Science and Technology* **49** : 214-220.

Doymaz, I., and Ismail, O. (2010). Drying and rehydration behaviors of green bell peppers. *Food Science and Biotechnology* **19** : 1449-1455.

Doymaz, I., and Ismail, O. (2011). Drying characteristics of sweet cherry. *Food and Bioproducts Processing* **89** : 31–38.

Duc, L. A.; Han, J. W.and Keum, D. H.,2011. Thin layer drying characteristics of rapeseed (Brassica napus L.). *Journal of Stored Products Research* **47**: 32-38.

El-Beltagy, A., Gamea, G.R., and Essa, A.H.A. (2007). Solar drying characteristics of strawberry. *Journal of Food Engineering* **78** : 456-464.

Emam-Ddjomeh, Z., Zadeh, R.Z., and Shahedi, M. (2007). Effects of drying methods on dehydration kinetics of pomegranate peel. The Proceedings of the 5th Asia-Pasific Drying Conference, Vol. 2 : 1165-1170.

Erbay, Z., and Icier, F. (2008b). Drying kinetics of olive leaves. *Gida* **33** : 165-173 (in Turkish).

Erbay, Z., and Icier, F. (2009). A review of thin layer drying of foods: theory, modeling, and experimental results. *Critical Reviews in Food Science and Nutrition* **50** : 441–464.

Erenturk, S., Gulaboglu, M.S., and Gultekin, S. (2004). The thin-layer drying characteristics of rosehip. *Biosystems Engineering* **89** : 159–166.

Ertekin, C., and Yaldiz, O. (2004). Drying of eggplant and selection of a suitable thin layer drying model. *Journal of Food Engineering* **63** : 349–359

Falade, K.O., and Solademi, O.J. (2010). Modelling of air drying of fresh and blanched sweet potato slices. *International Journal of Food Science and Technology* **45** : 278-288.

Fang, S., Wang, Z., and Hu X. (2009). Hot air drying of whole fruit Chinese jujube (Zizyphus jujuba Miller): thin-layer mathematical modelling. *International Journal of Food Science and Technology* **44** : 1818-1824.

Farmer, G.S., Brusewitz, G.H., and Whitney, R.W. (1983). Drying properties of bluestem grass seed. *Transaction of the ASAE* **26** : 234-237.

Faustino, J.M.F., Barroca, M.J., and Guine, R.P.F. (2007). Study of the drying kinetics of green bell pepper and chemical characterization. *Food and Bioproducts Processing, Trans IChemE, Part C* **85** : 163–170.

Friant, N.R., Marks, B.P., and Bakker-Arkema, F.W. (2003). Drying rate of individual ears of corn. ASAE Paper No: 2003-36006.

Fumagalli, F., and Freire, J.T. (2007). Analysis of the drying kinetics of brachiaria brizantha (hochst. Stapf) grass seeds at different drying modes. *Drying Technology* **25** : 1437–1444.

Ganesapillai, M., Miranda, L.R., Reddy, T., Bruno, M., and Singh, A. (2011). Modeling, characterization and evaluation of efficiency and drying indices for microwave drying of zingiber officianale and curcuma mangga. *Asia-Pasific Journal of Chemical Engineering* **6** : 912-920.

Garavand, A.T., Rafiee, S., and Keyhani, A.R. (2011). Mathematical modeling of thin layer drying kinetics of tomato: influence of air dryer conditions. *International Transaction Journal of Engineering, Management and Applied Sciences and Technologies* **2** : 147-160.

Ghazanfari, A., Emami, S., and Tabil, L.G. (2006a). Thin-layer drying of flax fiber: II. Modeling drying process using semi-theoretical and empirical models. *Drying Technology* **24** : 1637-1642.

Ghazanfari, A., Emami, S., Tabil, L.G., and Panigrahi, S. (2006). Thin layer drying of flax fiber: III. Influence of layer thickness on drying parameters. *Drying Technology* **24** : 1643-1648.

Goyal, R.K., Kingsly, A.R.P., Manikantan, M.R., and Ilyas, S.M. (2007). Mathematical modelling of thin layer drying kinetics of plum in a tunnel dryer. *Journal of Food Engineering* **79** : 176–180.

Guine, R.P.F., and Barroca, M.J. (2012). Effect of drying treatments on texture and color of vegetables (pumpkin and green pepper). *Food and Bioproducts Processing* **90** : 58-63.

Guine, R.P.F., Henrriques, F., and Barroca, M.J. (2012). Mass transfer coefficients for the drying of pumpkin and dried product quality. *Food Bioprocess Technology* **5**: 176-183.

Gunhan T., Demir V., and Hancioglu E. (2005). Mathematical modelling of drying of bay leaves. *Energy Conversion and Management* **46** : 1667-1679.

Hacihafizoglu, O., Cihan, A. and Kahveci, K. (2008). Mathematical modelling of drying of thin layer rough rice. *Food And Bioproducts Processing* **86** : 268–275.

Haghi, A.K., and Angiz, F.Z. (2007). Heat and mass transfer in thermal drying of wool: a theoretical approach. The Proceedings of the 5th Asia-Pasific Drying Conference, Vol.1 : 443-448.

Hasibuan, R., and Daud W.R.W. (2004). Through drying of oil palm empty fruit bunches fiber using superheated steam. Drying 2004, Silva, M.A., Rocha, S.C.S., Mujumdar, A.M. (Eds.), Proceedings of 14th IDS, Sao Paulo, Brazil, Vol.1 : 2027-2034.

Hassan, B.H., and Hobani, A. (2000). Thin-layer drying of dates. *Journal of Food Process Engineering* **23** : 177-189.

Hayaloglu, A.A., Karabulut, I., Alpaslan, M., and Kelbaliyev, G. (2007). Mathematical modeling of drying characteristics of strained yoghurt in a convective type tray deryer. *Journal of Food Engineering* **78** : 109-117.

Henderson, J.M., and Henderson, S.M. (1968). A computational procedure for deep-bed drying analysis. *Journal of Agricultural Engineering Research* **13** : 87–95.

Hii, C.L., Law, C.L., and Cloke, M. (2008). Modeling of thin layer drying kinetics of cocoa beans during artificial and natural drying. *Journal of Engineering Science and Technology* **3** : 1-10.

Hii, C.L., Law, C.L., and Cloke, M. (2009). Modeling using a new thin layer drying model and product quality of cocoa. *Journal of Food Engineering* **90** : 191–198.

Hossain, M.A., and Bala, B.K. (2002). Thin-layer drying characteristics for green chilli. *Drying Technology* **20** : 489–505.

Hossain, M.A., Woods, J.L., and Bala B.K. (2007). Single-layer drying characteristics and colour kinetics of red chilli. *International Journal of Food Science and Technology* **42** : 1367-1375.

Hui, Y.H., Clary, C., Farid, M.M., Fasina, O.O., Noomhorm, A., and Welti-Chanes J. (2008). Food Drying, Science and Technology. DEStech Pub. Inc., PA, USA.

Hustrulid, A., and Flikke, A.M. (1959). Theoretical drying curve for shelled corn. *Transactions of the ASAE* **2** : 112-114.

Hutchinson, D., and Otten, L. (1982). Thin layer drying of soybeans and white beans. CSAE Paper No : 82-104.

Iquaz, A., San Martin, M.B., Mate, J.I., Fernandez, T., and Virseda, P. (2003). Modelling effective moisture diffusivity of rough rice at low drying temperatures. *Journal of Food Engineering* **99** : 253-258.

Jain, D., and Pathare, P.B. (2004). Selection and evaluation of thin layer drying models for infrared radiative and convective drying of onion slices. *Biosystems Engineering* **89** : 289-296.

Janjai, S., Lamlert, N., Intawee, P., Mahayothee, B., Boonrod, Y., Haewsungcharern M., Bala, B.K., Nagle, M., and Muller, J. (2009). Solar drying of peeled longan using a side loading type solar tunnel dryer: experimental and simulated performance. *Drying Technology* **27** : 595-605.

Janjai, S., Lamlert, N., Mahayothee, B., Bala, B.K., Preceppe, M., and Muller, J. (2011a). Thin layer drying of peeled longan. *Food Science Technology Research* **17** : 279-288.

Janjai, S., Precoppe, M., Lamlert, N., Mahayothee, B., Bala, B.K., Nagle, M., and Muller, J. (2011b). Thin layer drying of litchi. *Food and Bioproducts Processing* **89** : 194-201.

Jayas, D.S., and Sokhansanj, S. (1989). Thin layer drying of barley at low temperatures. *CSAE* **31** : 21-23.

Jayas, D.S., Cenkowski, S., and Pabis, S. (1991). Review of thin-layer drying and wetting equations. *Drying Technology* **9** : 551-588.

Jazini, M.H., and Hatamipour, M.S. (2010). A new physical pretreatment of plum for drying. *Food and Bioproducts Processing* **88** : 133-137.

Jena, S., and Das, H. (2007). Modelling for vacuum drying characteristics of coconut presscake. *Journal of Food Engineering* **79** : 92–99.

Kadam, D.M., and Dhingra, D. (2011). Mass transfer kinetics of banana slices during osmo-convective drying. *Journal of Food Process Engineering* **34** : 511-532.

Kahveci, K., and Cihan, A. (2008). Drying of Food Materials: Transport Phenomena. Nova Science Publishers Inc.

Kailappan,R., and Kaleemullah, S. (2006). Modelling of thin-layer drying kinetics of red chillies. *Journal of Food Engineering* **76** : 531–537.

Kaleta, A., and Gornicki, K. (2010). Evaluation of drying models of apple (var. McIntosh) dried in a convective dryer. *International Journal of Food Science and Technology* **45** : 891-898.

Karaaslan S. N.; Tuncer I. K. 2008. Development of a drying model for combined microwave–fan-assisted convection drying of spinach. *Biosystems Engineering* **100** : 44 – 52.

Karabulut, I., Hayaloglu, A.A., Yildirim, H. (2007). Thin-layer drying characteristics of kurut, a Turkish dried dairy by-product. *International Journal of Food Science and Technology* **42** : 1080–1086.

Kashaninejad, M., Mortazavi, A., and Safekordi, A. (2007). Thin-layer drying characteristics and modeling of pistachio nuts. *Journal of Food Engineering* **78** : 98-108.

Kayisoglu S., Ertekin C. (2011). Vacuum drying kinetics of Barbunya bean. *Philippine Agricultural Scientist* **94** : 285-291.

Khazaei, J., and Daneshmandi, S. (2007). Modeling of thin layer drying kinetics of sesame seeds: mathematical and neural networks modeling. *International Agrophysics* **21** : 335-348.

Kingsly, A.R.P., Balasubramaniam, V.M., and Rastogi, N.K. (2009). Effect of high-pressure processing on texture and drying behavior of pineapple. *Journal of Food Process Engineering* **32** : 369-381.

Kingsly, R.P., Goyal, R.K., and Manikantan, M.R. (2007). Effects of pretreatments and drying air temperature on drying behaviour of peach slice. *International Journal of Food Science and Technology* **42** : 65-69.

Kiranoudis, C.T., Tsami, E., and Maroulis, Z.B. (1997). Microwave vacuum drying kinetics of some fruits. *Drying Technology* **15** : 2421-2440.

Kose, B., and Erenturk, S. (2010). Drying characteristics of mistletoe in convective and UV combined convective type dryers. *Industrial Crops and Products* **32** : 394-399.

Koua, K.B., Fassinou, W F., Gbaha, P., and Toure, S. (2009). Mathematical modelling of the thin layer solar drying of banana, mango and cassava. *Energy* **34**: 1594–1602.

Kulasiri, D.G., Vaughan, D.H., Cundiff, J.S., and Wilcke, W.F. (1989). Thin layer drying rates of Virginia type peanuts. ASAE Paper No : 89-6600.

Kumar, D.G.P., Hebbar, H.U., Ramesh, and M.N. (2006). Suitability of thin layer models for infrared-hot air-drying of onion slices. *LWT-Food Science and Technology* **39** : 700-705.

Kumar, N., Sarkar, B.C., and Sharma, H.K. (2012). Mathematical modeling of thin layer hot air drying of carrot pomace. *Journal of Food Science and Technology* **49** : 33-41.

Kurozawa, L.E., Azoubel, P.M., Murr, F.E.X., and Park, K.J. (2012). Drying kinetic of fresh and osmotically dehydrated mushroom (Agaricus Blazei). *Journal of Food Process Engineering* **35** : 295-313.

Lahsasni, S., Kouhila M., Mahrouz, M., Idlimam, A., and Jamali, A. (2004b). Thin layer convective solar drying and mathematical modeling of prickly pear peel. *Energy* **29** : 211-224.

Lahsasni, S., Kouhila, M., and Mahrouz, M. (2004a). Drying kinetics of prickly pear fruit (Opuntia ficus indica). *Journal of Food Engineering* **61** : 173-179.

Lahsasni, S., Kouhila, M., Mahrouz, M., Ait Mohamed, L., and Agorram, B. (2004c). Characteristic drying curve and mathematical modeling of thin layer solar drying of prickly pear cladode. *Journal of Food Process Engineering* **27** : 103-117.

Laohavanich, J., and Wongpichet, S. (2008). Thin layer drying model for gas fired infrared drying of paddy. *Songklanakarin J. Sci. Technol.* **30** : 343-348.

Lee, J.H., and Kim, H.J. (2009). Vacuum drying kinetics of Asian white radish (raphanus sativus l.) slices. *LWT-Food Science and Technology* **42** :180–186.

Lemus-Mondaca, R., Betoret, N., and Vega-Galvez, A. (2009). Dehydration characteristics of papaya (carica pubenscens): determination of equilibrium moisture content and diffusion coefficient. *Journal of Food Process Engineering* **32** : 645-663.

Li, H., Morey, R.V., and Afinrud, M. (1987). Thin layer drying rates of oilseed sunflower. *Transactions of the ASAE* **30** : 1172-1175, 1180.

Lima, O.C.M., and Massarani, G. (1995). Estudo sobre a secagem de papel III: Uma analise nas equacoes de secagem. Anais do XXIII Congresso Brasileiro de Sistemas Particulados, Maringa, PR, Brasil, Vol.1 : 431-440.

Liu, X., Qiu, Z., Wang, L., Cheng, Y., Qu, H., and Chen, Y. (2009). Mathematical modeling for thin layer vacuum belt drying of Panax notoginseng extract. *Energy Conversion and Management* **50** : 928–932.

Lopez, A., Pique, M.T., Boatella, J., Ferran, A., Garcia, J., and Romero, A. (1998). Drying characteristics of the hazelnut. *Drying Technology* **16** : 627-649.

Lopez, R., De Ita, A., Vaca, M. (2009). Drying of prickly pear cactus cladodes (Opuntia ficus indica) in a forced convection tunnel. *Energy Conversion and Management* **50** : 2119-2126.

Luikov, A.V. (1968). Analytical Heat Diffusion Theory. Academic Press.

Madamba, P.S. (2003). Thin layer drying models for osmotically pre-dried young coconut. *Drying Technology* **21** : 1759–1780.

Madhiyanon, T., Phila, A., and Soponronnarit, S. (2009). Models of fluidized bed drying for thin-layer chopped coconut. *Applied Thermal Engineering* **29** : 2849-2854.

Magalhaes, A., and Pinho, C. (2008). Spouted bed drying of cork stoppers. *Chemical Engineering and Processing* **47** : 2395–2401.

Meisami-Asl, E., and Rafiee, S. (2009). Mathematical modeling of kinetics of thin-layer drying of apple (var. Golab). Agricultural Engineering International: the CIGR E-journal, Manuscript 1185, Vol. XI.

Meisami-Asl, E., Rafiee, S., Keyhani, A., and Tabatabaeefar, A. (2010). Determination of suitable thin layer drying curve model for apple slices. Plant Omics Journal 3 : 103-108.

Menges H.O., and Ertekin, C. (2006b). Thin layer drying model for treated and untreated Stanley plums. *Energy Conversion and Management* **47** : 2337-2348**.**

Menges, H.O., and Ertekin, C. (2006a). Mathematical modeling of thin layer drying of Golden apples. *Journal of Food Engineering* **77** : 119-125.

Menges, H.O., and Ertekin, C. (2006c). Modelling of air drying of Hacıhaliloglu-type apricots. *J. Sci. Food. Agric.* 86 : 279–291.

Midilli, A., and Kucuk, H. (2003). Mathematical modeling of thin layer drying of pistachio by using solar energy. *Energy Conversion and Management* **44** : 1111-1122.

Midilli, A., Kucuk, H., and Yapar, Z. (2002). A new model for single-layer drying. *Drying Technology* **20** : 1503–1513.

Misra, M.K., and Brooker, D.B. (1980). Thin layer drying and rewetting equations for shelled yellow corn. *Transactions of the ASAE* **23** : 1254-1260.

Mota, C.L., Luciano, C., Diasa, A., Barroca, M.J., and Guine, R.P.F. (2010). Convective drying of onion: kinetics and nutritional evaluation. *Food and Bioproducts Processing* **88** : 115–123.

Mundada, M., Hathan, B.S., and Maske, S. (2010). Convective dehydration kinetics of osmotically pretreated pomegranate arils. *Biosystem Engineering* **107** : 307-316.

Neter, J., Wasserman, W., and Kutner, M.H. (1990). Applied Linear Statistical Models. Regression Analysis of Variance and Experimental Designs. Richard D. Irwin Inc., USA.

Noomhorn, A., and Verma, L.R.A. (1986). A generalized single layer rice drying model. ASAE Paper No: 86-3057, ASAE, St. Joseph, MI.

Nourhene, B., Mohammed, K., and Nabil, K. (2008). Experimental and mathematical investigations of convective solar drying of four varieties of olive leaves. *Food and Bioproducts Processing* **86** : 176–184.

O'Callaghan, J.R., Menzies, D.J., Bailey, P.H. (1971). Digital simulation of agricultural drier performance. *Journal of Agricultural Engineering Research* **16** : 223-244.

Oman, S.D. (1991). Multiplicative effects in mixed model analysis of variance. *Biometrika* **78** : 729–739.

Otsura, K., Murata, S., and Chuma, Y. (1975). An empirical equation for thin layer drying of rough rice with heated air. *Journal of Japanese Agricultural Machinery* **37** : 331-338 (in Japanese).

Overhults, D.G., Ross, I.J., White, G.M., and Hamilton, H.E. (1973). Drying soybeans with heated air. *Transactions of the ASAE* **16** : 112-113.

Ozbek, B., and Dadali, G. (2007). Thin-layer drying characteristics and modelling of mint leaves undergoing microwave treatment. *Journal of Food Engineering* **83** : 541–549.

Pabis, S., Jayas, D.S., and Cenkowski, S. (1998). Grain Drying, Theory and Practice. John Wiley and Sons Inc.

Panchariya, P.C., Popovic, D., and Sharma, A.L. (2002). Thin-layer modelling of black tea drying process. *Journal of Food Engineering* **52** : 349-357.

Pardeshi, I.L., and Chattopadhyay, P.K. (2010). Hot air puffing kinetics for soy-fortified wheat-based ready-to-eat (rte) snacks. *Food and Bioprocess Technology* **3** : 415-426.

Pardeshi, I.L., Arora, S., and Borker, P.A. (2009). Thin-layer drying of green peas and selection of a suitable thin-layer drying model. *Drying Technology* **27** : 288-295.

Patil, B.G., and Ward, G.T. (1989). Heated air drying of rapeseed. *Agricultural Mechanization in Asia, Africa and Latin America* **20** : 52-58.

Patil, R.T. (1995). Drying characteristics of alfalfa crops. PhD Agricultural and bioresource Engineering, University of Saskatchewan, Saskatoon, S7N5A9.

Paulsen, M.R., and Thompson, T.L. (1973). Drying endysus of grain sorghum. *Transactions of the ASAE* **16** : 537-540.

Phoungchandang, S., and Kongpim, P. (2012). Modeling using a new thin layer drying model and drying characteristics of sweet basil using tray and heat pump assisted dehumidified drying. *Journal of Food Process Engineering* **35** : 851-862.

Purkayastha, M.D., Nath, A., Deka, B.C., and Mahanta, C.L. (2011). Thin layer drying of tomato slices. *Journal of Food Science and Technology* DOI 10.1007/s13197-011-0397-x.

Queiroz, R., Gabas, A.L., and Telis, V.R.N. (2004). Drying kinetics of tomato by using eletric resistance and heat pump dryers. *Drying Technology* **22** : 1603-1620.

Rafiee, S., Keyhani, A.R., and Jafari, A. (2008). Modeling effective moisture diffusivity of wheat (Tajan) during air drying. *International Journal of Food Properties* **11** : 223-232.

Resende, O., Arcanjo, R.V., and Siqueira, V.C. (2009). Mathematical modeling for drying coffee (*Coffea canephora Pierre*) berry clones in concrete yard. *Acta Scientiarum-Agronomy* **31** : 189-196.

Roberts, J.S., Kidd, D.R., and Padilla-Zakour, O. (2008). Drying kinetics of grape seeds. *Journal of Food Engineering* **89** : 460-465.

Rowe, R.J., and Gunkel, W.W. (1972). Simulation of temperatre and moisture content of alfalfa during thin layer drying. *Transactions of the ASAE* **15** : 805-810.

Sacilik, K., and Elicin, A. K. (2006). The thin layer drying characteristics of organic apple slices. *Journal of Food Engineering* **73** : 281–289.

Sacilik, K., and Unal, G. (2005). Dehydration characteristics of Kastamonu garlic slices. *Biosystems Engineering* **92** : 207-215.

Sacilik, K., Keskin, R., and Elicin, A.K. (2006). Mathematical modelling of solar tunnel drying of thin layer organic tomato. *Journal of Food Engineering* **73** : 231-238.

Sander, A., and Kardum, J.P. (2009). Experimental validation of thin-layer drying models. *Chem. Eng. Technol.* **32** : 590–599.

Sankat, C.K., Castaigne, F., Maharaj, R. (1996). The air drying behavior of fresh and osmotically dehydrated banana slices. *International Journal of Food Science and Technology* **31** : 123-135.

Sawhney, R.L., Sarsavadia, P.N., Pangavhane, D.R., and Singh, S.P. (1999). Determination of drying constants and their dependence on drying air parameters for thin layer onion drying. *Drying Technology* **17** : 299-315.

Schwarz, G. 1978. Estimating the dimensional of a model. *Ann. Stat.* **6** : 461-464.

Sharaf-Eldeen, Y.I., Blaisdell, J.L., and Hamdy, M.Y. (1980). A model for ear corn drying, *Transactions of the ASAE* **23** : 1261-1265, 1271.

Sharma, G.P., Verma, R.C., and Pathare, P. (2005). Mathematical modeling of infrared radiation thin layer drying of onion slices. *Journal of Food Engineering* **71** : 282-286.

Shi, J., Pan, Z., Mchugh, T.H., Wood, D., Hirschberg, E., and Olson, D. (2008). Drying and quality characteristics of fresh and sugar-infused blueberries dried with infrared radiation heating. *LWT - Food Science and Technology* **41** : 1962-1972.

Shi, Q., Zheng, Y., and Zhao, Y. (2013). Mathematical modeling on thin layer heat pump drying of yacon slices. *Energy Conversion and Management* **71** : 208-216.

Shittu, T.A., and Raji, A.O. (2011). Thin layer drying of African breadfruit (Treculia africana) seeds: modeling and rehydration capacity. *Food and Bioprocess Technology* **4** : 224-231.

Singh, B., Panesar, P.S., Gupta, A.K., and Kennedy, J.F. (2006). Sorption isotherm behavior of osmoconvectively dehydrated carrot cubes. *Journal of Food Processing and Preservation* **30** : 684–698.

Sobukola, O.P., Dairo, O.U., Odunewu, A.V. (2008). Convective hot air drying of blanched yam slices. *International Journal of Food Science and Technology* **43** : 1233-1238.

Soponronnarit, S., Swasdisevi, T., Wetchacama, S., Wutiwiwatchai, W. (2001). Fluidised bed drying of soybeans. *Journal of Stored Products Research* **37** : 133-151.

Soysal, Y., Oztekin, S., and Eren, O. 2006. Microwave drying of parsley: modelling, kinetics, and energy aspects. *Biosystems Engineering* **93** : 403–413.

Sripinyowanich, J. and Noomhorm, A. (2011). A new model and quality of unfrozen and frozen cooked rice dried in a microwave vibro-fluidized bed dryer. *Drying Technology* **29** : 735–748.

Sun, D.W., and Woods, J.L. (1994). Low temperature moisture transfer characteristics of barley: thin layer models and equilibrium isotherms. *Journal of Agricultural Engineering Research* **59** : 273-283.

Tabatabaee, R., Jayas, D.S., and White N.D.G. (2004) Thin layer drying and rewetting characteristics of buckwheat. *Canadian Biosystems Engineering* **46** : 19-24.

Tahmasebi, M., Hashjin, T.T., Khoshtaghaza, M.H., and Nikbakht, A.M. (2011). Evaluation of thin layer drying models for simulation of drying kinetics of quercus. *J. Agric. Sci. Tech.* **13** : 155-163.

Tang, J., Sokhansanj, S, and Sosulski, F.W. (1989). Thin layer drying of lentil. ASAE Paper No: 89-6540.

Therdthai, N., and Northongkom, H. (2011). Characterization of hot air drying and microwave vacuum drying of fingerroot (Boesenbergia pandurata). *International Journal of Food Science and Technology* **46** : 601-607.

Thompson, T.L., Peart, R.M., and Foster, G.H. (1968). Mathematical simulation of corn drying: A new model. *Transactions of the ASAE* **11** : 582–586.

Thorat, I.D., Mohapatra, D., Sutar, R.F., Kapdi, S.S., and Jagtap, D.D. 2012. Mathematical modeling and experimental study on thin layer vacuum drying of ginger. *Food Bioprocess Technology* **5** : 1379. 1383.

Tirawanichakul, S., Tirawanichakul, Y., and Sniso, E. (2008). Paddy dehydration by adsorption: Thermo-physical properties and diffusion model of agriculture residues. *Biosystem Engineering* **99** : 249-255.

Tironi, A., Crozza, D.E., and Pagano, A.M. (2004). Drying kinetics of carthamus tinctorius L. seeds. Proceedings of the 14th International Drying Symposium, Vol. C, pp. 1612-1619.

Togrul I.T., and Pehlivan, D. (2002). Mathematical modelling of solar drying of apricots in thin layers. *Journal of Food Engineering* **55** : 209–216

Togrul, H. (2005). Simple modeling of infrared drying of fresh apple slices. *Journal of Food Engineering* **71** : 311-323.

Togrul, H. (2006). Suitable drying model for infrared drying of carrot. *Journal of Food Engineering* **77** : 610–619.

Togrul, I.T. (2010). Modelling of heat and moisture transport during drying black grapes. *International Journal of Food Science and Technology* 45 : 1146-1152.

Togrul, I.T., and Pehlivan, D. (2003). Modelling of drying kinetics of single apricot. *Journal of Food Engineering* **58** : 23-32.

Togrul, I.T., and Pehlivan, D. (2004). Modeling of thin layer drying kinetics of some fruits under open air sun drying process. *Journal of Food Engineering* **65** : 413-425.

Tripathy, P.P., and Kumar, S. (2008). Determination of temperature dependent drying parameters for potato cylinders and slices during solar drying. *Energy Conversion and Management* **49** : 2941–2948.

Tunde-Akintunde, T.Y. (2011). Mathematical modeling of sun and solar drying of chilli pepper. *Renewable Energy* **36** : 2139-2145.

Usub, T., Lertsatitthankorn, C., Poomsaad N., Wiset, L., Siriamornpun, S., and Soponronnarit, S. (2010). Thin layer solar drying characteristics of silkworm pupae. *Food and Bioproducts Processing* **88** : 149–160.

Varadharaju, N., Karunanidhi, C., and Kailappan, R., (2001). Coffee cherry drying: A two-layer model. *Drying Technology* **19** : 709–715.

Vega, A., Uribe, E., and Lemus, R. (2007). Hot-air drying characteristics of Aloe vera *(Aloe barbadensis Miller*) and influence of temperature on kinetic parameters. *LWT-Food Science and Technology* **40** : 1698-1707.

Vega-Galvez, A., Andres, A., Gonzalez, E., Notte-Cuello, E., Chacana, M., and Lemus-Mondaca, R. (2009a). Mathematical modelling on the drying process of yellow squat lobster (*Cervimunida jhoni*) fishery waste for animal feed. *Animal Feed Science and Technology* **151** : 268–279

Vega-Galvez, A., Dagnino-Subiabre, A., Terreros, G., Lopez, J., Miranda, M., and Di Scala, K. (2011). Mathematical modeling of convective air drying of quinoa-supplemented feed for laboratory rats. *Brazilian Archives of Biology and Technology International Journal* **54** : 161-171.

Vega-Galvez, A., Lemus-Mondaca, R., and Bilbao-Sainz, C. (2008a). Mass transfer kinetics during convective drying of red pepper var. Hungarian (Capsicum annuum L.): mathematical modeling and evaluation of kinetic parameters. *Journal of Food Process Engineering* **31** : 120-137.

Vega-Galvez, A., Lemus-Mondaca, R., Tello-Ireland, C., Miranda, M., and Yagnam, F. (2009b). Kinetic study of convective drying of blueberry variety O'Neil (*Vaccinium corymbosum* L.). *Chilean Journal Of Agricultural Research* **69** :171-178.

Vega-Galvez, A., Martin, R.S., Sanders, M., Miranda, M., and Lara, E. (2010). Characteristics and mathematical modeling of convective drying of quinoa (*Chenopodium Quinoa* Willd.): influence of temperature on the kinetic parameters. *Journal of Food Processing and Preservation* **34** : 945–963.

Vega-Galvez, A., Miranda, M., Bilbao-Sainz, C., Uribe, E., and Lemus-Mondaca, R. (2008b). Empirical modeling of drying process for apple (cv. *Granny Smith*) slices at different air temperatures. *Journal of Food Processing and Preservation* **32** : 972–986.

Vega-Galvez, A., Notte-Cuello, E., and Lemus-Mondaca, R. (2009c). Mathematical modelling of mass transfer during rehydration process of Aloe vera (Aloe barbadensis Miller). *Food and Bioproducts Processing* **87** : 254-260.

Vengaiah, P.C., and Pandey, J.P. (2007). Dehydration kinetics of sweet pepper (Capsicum annum L.). *Journal of Food Engineering* **81** : 282–286

Verma, L.R., Bucklin, R.A., Endan, J.B., and Wratten, F.T. (1985). Effects of drying air parameters on rice drying models. *Transactions of the ASAE* **28** : 296–301.

Vijayaraj, B., Saravanan, R., and Renganarayanan, S. (2007). Studies on thin layer drying of bagasse. *International Journal of Energy Research* **31** : 422–437.

Wang, C.Y., and Singh, R.P. (1978). A single layer drying equation for rough rice. ASAE Paper No : 3001.

Wang, D.C., Fon, D.S., Fang, W., and Sokhansanj, S. (2004). Development of a visual method to test the range of applicability of thin layer drying equations using MATLAB tools. *Drying Technology* **22** : 1921–1948.

Wang, J. (2002). A single layer model for far infrared radiation drying of onion slices. *Drying Technology* **20** : 1941-1953.

Wang, Z., Sun, J., Chen, F., Liao, X., and Hu, X. (2007a). Mathematical modelling on thin layer microwave drying of apple pomace with and without hot air pre-drying. *Journal of Food Engineering* **80**: 536–544.

Wang, Z., Sun, J., Liao X., Chen, F., Zhao G., Wu, J., and Hu, X. (2007b). Mathematical modeling on hot air drying of thin layer apple pomace. *Food Research International* **40** : 39-46.

Wang, Z.F., Fang, S.Z., and Hu, X.S. (2009). Effective Diffusivities And Energy Consumption Of Whole Fruit Chinese Jujube (Zizyphus Jujuba Miller) In Microwave Drying. *Drying Technology* **27** : 1097–1104.

Westerman, P.W., White, G.M., and Ross, I.J. (1973). Drying rate and quality of white shelled corn as influenced by dew point temperature. *Transactions of the ASAE* **16** : 118-120.

White, G.M., Bridges, T.C., Loewer, O.J., and Ross, I.J. (1978). Seed coat damage in thin layer drying of soybeans as affected by drying conditions. ASAE Paper No: 78-3052.

White, G.M., Ross, I.J., and Poneleit, C.G. (1981). Fully exposed drying popcorn. *Transactions of the ASAE* **24** : 466-468.

Wolfinger, R. (1993). Covariance structure selection in general mixed models. *Commun.Stat-Simul.* **22** : 1079–1106.

Wongwises, S., and Thongprasert, M. (2000). Thin layer and deep bed drying of long grain rough rice. *Drying Technology* **18** : 1583-1599

Xanthopoulos, G., Lambrinos, G., and Manolopoulou, H. (2007a). Evaluation of thin-layer models for mushroom (Agaricus Bisporus) drying. *Drying Technology* **25** : 1471–1481.

Xanthopoulos, G., Oikonomou, N., and Lambrinos, G. (2007b). Applicability of a single layer drying model to predict the drying rate of whole figs. *Journal of Food Engineering* **81** : 553-559.

Yaldiz, O., and Ertekin, C. (2001). Thin layer solar drying of some vegetables. *Drying Technology* **19** : 583-597.

Yaldiz, O., Ertekin, C., and Uzun, H.I. (2001). Mathematical modeling of thin layer solar drying of sultana grapes. *Energy* **26** : 457-465.

Yang, C.Y., Fon, D.S., and Lin, T.T., (2007). Simulation and validation of thin layer models for peanut drying. *Drying Technology* **25** : 1515–1526.

Yesilova, A., Kaydan, M.B., and Kaya, Y. (2010). Modeling insect-egg data with excess zeros using zero-inflated regression models. *Hacettepe Journal of Mathematics and Statistics* **39** : 273-282.

Yi, X.K., Wu, W.F.; Zhang, Y.Q.; Li, J.X., and Luo, H.P. (2012). Thin layer drying characteristics and modeling of Chineese jujubes. Mathematical problems in Engineering, Article ID: 386214, 18 pages.

Zenoozian, M.S., Feng, H., and Razavi, S.M.A. (2008). Image analysis and dynamic modeling of thin-layer drying of osmotically dehydrated pumpkin. *Journal of Food Processing and Preservation* **32** : 88-102.

Zomorodian, A., and Moradi, M. 2010. Mathematical modeling of forced convection thin layer solar drying for cuminum cyminum. *J. Agr. Sci. Tech.* **12** : 401-408.