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*Full Length Research Paper*

# Moisture desorption isotherms of *Lavandula officinalis* L. leaves at three temperatures

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**Lavander has been used as a medicinal and aromatic plant and to treat several diseases. Knowledge of moisture desorption isotherms is useful in food dehydration and drying. Moisture equilibrium data of *Lavandula officinalis* L. leaves were determined by using the gravimetric static method with water activity ranging from 11 to 85% and three temperatures of 30, 40 and 50°C. Five mathematical models (modified Henderson, modified Oswin, modified Halsey, modified Chung – Pfost and GAB equations) were used to fit the experimental data of desorption. The modified Chung – Pfost model was the most suitable model for estimating desorption isotherms curves.**

**Key words:** *Lavandula officinalis* L., equilibrium moisture content, desorption.

## INTRODUCTION

*Lavandula officinalis* L. is an important medicinal plant that belongs to the Labiatae family. It is native to many parts of Iran. Linalool and linalyl acetate are the main component of lavender oils. The relationship between equilibrium relative humidity (ERH) and equilibrium moisture content (EMC) is normally defined by moisture sorption isotherms (Soysal and Öztekin 1999). In practice, the result of moisture exchange between the product and the surrounding air yields a relative humidity which is known as the equilibrium relative humidity (ERH) (Silakul and Jindal, 2002). EMC is defined as the moisture content of hygroscopic material in equilibrium with a particular environment in terms of temperature and relative humidity (Soysal and Öztekin, 1999). Moisture desorption isotherms help us to determine the maximum moisture that the plant can be allowed to lose during drying. Since all the agricultural products are generally hygroscopic, it is important to determine their equilibrium moisture content for drying, storing, mixing and packaging operations. Having different physical and chemical structures, agricultural crops demonstrate different EMCs under similar conditions (Ahmadi et al., 2010).

The common technique for measuring sorption properties is the static method. This method benefits from the ability to maintain constant conditions (Arnosti et al., 1999). Temperature and relative humidity of the environment in which samples are placed, are adjusted. When sample mass attains a constant level, sample moisture content is measured and adopted as the equilibrium moisture content (EMC) value. Several empirical and semi-empirical equations (modified Henderson, modified Oswin, modified Halsey, modified Chung – Pfost and GAB equations) have been reported to provide a correlation for the sorption isotherm values of agricultural and food products, including aromatic and medicinal plants (Belghit et al., 2000). However, no single equation is comprehensive enough to predict the relationship between the EMC of agricultural and food products and the relative humidity over a wide range of temperature (Lahsasni et al., 2004).

The objective of this study was to determine the desorption isotherms of *L. officinalis* L. leaves at relative humidity and temperature levels ranging from 11 to 85% and from 30 to 50°C, respectively. These temperatures were selected because they are often used in drying of medicinal plants.

## MATERIALS AND METHODS

### Experimental procedure

The *L. officinalis* L. fresh leaves used in desorption experiments have been grown in the Institute of Medicinal Plant of Iran in 2010.

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**Table 1.** Saturated salt solutions and equilibrium relative humidities at different temperatures.

| Salt type | Equilibrium relative humidity (ERH) | | |
|---|---|---|---|
| | T=30°C | T=40°C | T=50°C |
| LiCl | 0.113 | 0.112 | 0.111 |
| $CH_3COOK$ | 0.216 | 0.204 | 0.192 |
| $MgCl_2$ | 0.324 | 0.316 | 0.305 |
| $K_2CO_3$ | 0.432 | 0.432 | 0.433 |
| $NaNO_2$ | 0.643 | 0.616 | 0.597 |
| NaCl | 0.751 | 0.747 | 0.744 |
| KCl | 0.836 | 0.823 | 0.812 |

**Table 2.** Mathematical models applied to the desorption isotherms data of *Lavandula officinalis* L. leaves .

| Model name | Model expression | References |
|---|---|---|
| Modified Henderson | $EMC = \left(-\frac{1}{C_1(T+C_2)} Ln(1-ERH)\right)^{1/C_3}$ | (Thompson et al., 1968) |
| Modified Halsey | $EMC = \left(\frac{-\exp(C_1+C_2T)}{Ln(ERH)}\right)^{1/C_3}$ | (Iglesias and Chirife, 1976) |
| Modified Oswin | $EMC = (C_1 + C_2T)\left(\frac{ERH}{1-ERH}\right)^{1/C_3}$ | (Brooker et al., 1974) |
| Modified Chung-Pfost | $EMC = \frac{1}{C_1} Ln\left(Ln(ERH)\frac{(C_2-T)}{C_3}\right)$ | (Chung and Pfost, 1967) |
| GAB equation | $EMC = \frac{C_1C_2C_3(ERH)}{[1-C_2(ERH)][1-C_2(ERH)+C_2C_3(ERH)]}$ | (Van den Berg and Bruin, 1981) |

After harvesting, the leaves were cut from stems immediately. 1 g (± 0.0001) samples of fresh leaves for desorption experiments were weighed and placed into the glass jars. The equilibrium moisture content of *L. officinalis* L. leaves were determined by using the static gravimetric method at 30, 40 and 50°C. In this method, seven saturated salt solutions (LiCl, $CH_3$ COOK, $MgCl_2$, $K_2CO_3$, $NaNO_2$, NaCl and KCl) with relative humidities ranging from 11 to 85% were used to maintain relative humidities in the jars (Greenspan, 1976).

Table 1 gives the equivalent relative humidities for the selected salt solutions at three temperatures. The weight recording period was about 3 days until constant weight was reached. Crystalline thymol was used in the jars to prevent microbial spoilage. Constant weight was reached after about 4 weeks in different levels of temperature and relative humidities. The moisture content of each sample was determined in a drying oven at 105°C for 24 h (AOAC 1990).

### Data analysis

Table 2 shows five models, namely, modified Henderson, Oswin, Halsey, Chung – Pfost and GAB equations were used for correlating and defining the relationship between the equilibrium moisture content data and relative humidity at three temperatures (Chung and Pfost, 1967). $C_2$ and $C_3$ in the GAB equation were determined by using the following equations (Arabhosseini et al., 2005).

$$C_2 = C_4 exp\left(\frac{C_6}{RTa}\right) \quad (1)$$

$$C_3 = C_5 exp\left(\frac{C_7}{RTa}\right) \quad (2)$$

A nonlinear regression estimation package STATISTICA 5.0 was used to find the constants of models in desorption experiment (Chen, 2002). Mean relative deviation (MRD), determination coefficient ($R^2$), residual sum of squares (RSS), and standard error estimation (SEE) were used to evaluate the fitting quality of models.

$$SEE = \sqrt{\frac{\sum_{i=1}^{m}(EMC - \overline{EMC})^2}{df}} \quad (3)$$

$$MRD = \frac{1}{m}\sum_{i=1}^{m}\frac{|EMC - \overline{EMC}|}{EMC} \quad (4)$$

$$RSS = \sum_{i=1}^{m}(EMC - \overline{EMC})^2 \quad (5)$$

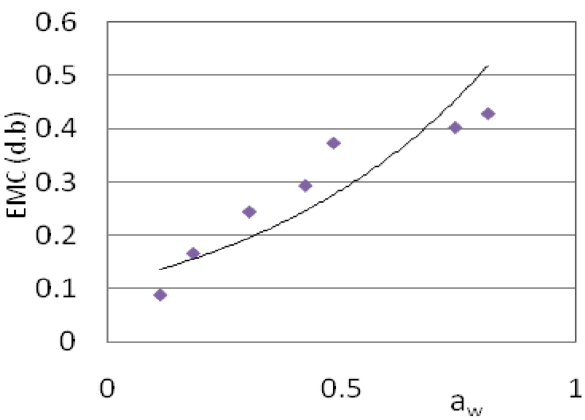


**Figure 1.** Desorption isotherms data of *Lavandula officinalis* L. leaves at 30°C and fitted curve of the Chung – Pfost model.

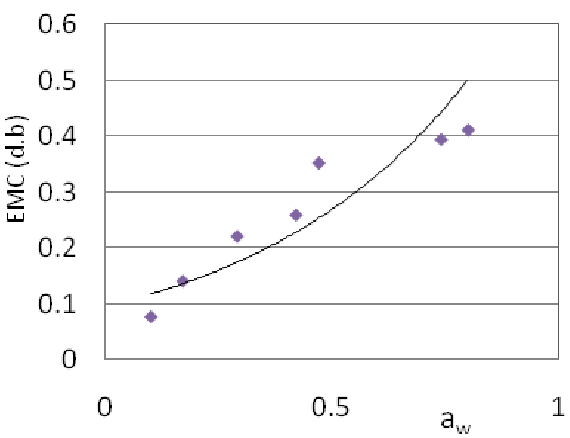


**Figure 2.** Desorption isotherms data of *Lavandula officinalis* L. leaves at 40°C and fitted curve of the Chung – Pfost model.

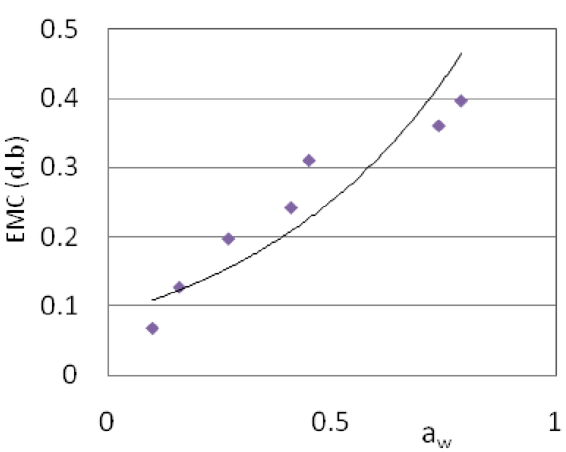


**Figure 3.** Desorption isotherms data of *Lavandula officinalis* L. leaves at 50°C and fitted curve of the Chung – Pfost model.

## RESULTS AND DISCUSSION

### Experimental results

Figures 1, 2 and 3 illustrates desorption isotherms of *L. officinalis* L. leaves obtained at various water activities for three temperature levels of 30, 40 and 50°C. As shown, S- shaped curves were found for all three temperatures similar to the most biological products (Ait Mohamed et al., 2005; Kouhila et al., 2002; Lahsasni et al., 2003). On the other hand, the full range of water activities and temperatures had a significant effect on EMC and with decreasing temperature in a constant relative humidity, the EMC was increased (Figures 1, 2 and 3). Such behavior may be explained by considering the excitation state of molecules. At high temperatures, molecules are in an increased state of excitation, leading to weaker attractive forces. This in turn, results in a decrease in the degree of water sorption at a given relative humidity with increasing temperature (Kouhila et al., 2002).

### Fitting of the desorption models to equilibrium moisture data

Desorption curves of *L. officinalis* L. were fitted to five isotherm models. The results of non- linear regression analysis at the three temperatures are listed in Tables 3 and 4. As inferred from the tables, parameters were found to be temperature dependent for all the models. The modified Chung – Pfost equation provided the best fit to experimental data of desorption isotherms with the maximum $R^2$ = 0.99 and the lowest MRD = 0.112 and SEE = 0.031, respectively.

### Conclusions

Moisture desorption curves of *Lavandula officinalis* L. leaves were obtained at three temperatures (30, 40, 50ºC) and relative humidity levels ranging from 11 to 85%. Statistical analysis was used to determine the best equation for predicting the desorption curves of *Lavandula officinalis* L. leaves. Chung – Pfost equation was the best fit with lowest error.

**Nomenclature: $C_1$ , $C_2$ , $C_3$ , $C_4$ $C_5$ , $C_6$ and $C_7$,** Equation coefficients; **RSS,** residual sum of square; **T,** temperature (°C); **SEE,** standard error estimation; **Ta,** absolute temperature (K); **MRD,** mean relative deviation; **R,** universal gas constant (kJ/kmol k); **df,** degrees of freedom; **$R^2$,** determination coefficient; **EMC,** equilibrium moisture content; **ERH,** equilibrium relative humidity (decimal); **d.b,** dry basis; **I,** sample number; **m,** Number of samples.

**REFERENCES**


Ahmadi CH, Minaei S, Bassiri AR, Almassi M, Arabhosseini A (2010). Moisture desorption isotherms of St. John's wort (*Hypericum perforatum* L.) leaves at three temperatures. Int. J. Food, Agri. and Envi (JFAE), 8(3&4): 132-135.

Ait ML, Kouhila M, Lahsasni S, Jamali A, Rhazi M (2005). Equilibrium moisture content and heat of sorption of *Gelidium* sesquipedale. J. Stored Prod. Res., 41: 199-209.

Arabhosseini A, Huisman W, Boxtel A, Muller J (2005). Modeling of the equilibrium moisture content (EMC) of tarragon (*Artemisia dracunculus* L.). Inter. J. Food Eng., 1(5): art7.

Arnosti JS, Freire JT, Sartori DJ, Barrozo MAS(1999). Equilibrium moisture content of *Brachiari brizantha*. Seed Sci. Tech., 27(1): 273-282.

Association of Official Analytical Chemists (AOAC) (1990). Official Methods of Analysis: 930.04. Moisture Content in Plants, 1: 949.

Belghit A, Kouhila M, Boutaleb BC (2000). Experimental study of drying kinetics by forced convection of aromatic plants. Energy Conversion Manage., 44: 1303-1321.

Brooker DB, Arkena FW, Hall CW (1974). Drying Cereal Grains. The AVI Publishing Company, Connecticut.

Chen C (2002). Sorption isotherms of sweet potato slice. J. Biosyst. Eng., 83(1): 85-95.

Chung DS, Pfost HB (1967). Adsorption and desorption of water vapor by cereal grains and their products. Trans. ASAE., 10(4): 549-557.

Greenspan L (1976). Humidity fixed points of binary saturated aqueous solutions. J. Res. Nat. Bureau Standards A. Phys. Chem., 81A(1): 86-96.

Iglesias H, Chirife J (1976). Prediction of effect of temperature on water sorption isotherms of food materials. J. Food Tech., 11: 109-16.

Kouhila M, Kechaou N, Otmani M, Fliyou M, Lahsasni S (2002). Experimental study of sorption isotherms and drying kinetics of Moroccan *Eucalyptus globules*. Drying Tech., 20: 2027-2039.

Lahsasni S, Kouhila M, Mahrouz M, Fliyou M (2003). Moisture adsorption-desorption isotherms of Prickly Pear cladode (*Opuntia ficus indica*) at different temperatures. Energy Conversion Manage., 44: 923-936.

Lahsasni S, Kouhila M, Mahrouz M (2004). Adsorption- desorption isotherms and heat of sorption of prickly pear fruit (Opuntia ficus indica). Energy Conversion Manage., 45(2): 249-251.

Silakul T, Jindal VK (2002). Equilibrium moisture content isotherms of mungbean. Inter. J. Food Properties, 5(1): 25-35.

Soysal Y, Öztekin S (1999). Equilibrium moisture content equation for some medicinal and aromatic plants. J. Agric. Eng. Res., 74(3): 317-324.

Thompson TL, Peart RM, Foster GH (1968). Mathematical simulation of corn drying- A new model. Trans. ASAE, 1(4): 582-586.

Van den Berg C, Bruin S (1981). Water activity and its estimation in food systems: theoretical aspects. In L. B. Rockland & G. F. Stewart (Eds), water activity: influences on food quality. New York: Academic Press, pp. 1-16.