Evaluation of energy consumption and special energy required for drying of *Hypericum perforatum L.*

Hossein AhmadiChenarbon[1*], Saeid Minaei [2], Akbar Arabhosseini[3], Ali Motevali[4]

1. Department of Agriculture, Varamin Pishva Branch, Islamic Azad University , Varamin Pishva, Iran.
2. Department of Agricultural Machinery Eng. Tarbiat Modares University, Tehran, Iran
3. College of Abouraihan, University of Tehran, Tehran, Iran.
4. Department of Engineering, Islamic Azad University, Shahre Qods Branch, Qods City, Tehran, Iran.

*Corresponding author: email: h.ahmadi@iauvaramin.ac.ir

Abstract: Drying is one of the most important post harvest processes which convert decaying products to resistant preparations so that it increases the storage duration and keeping product quality (food stuff shelflife). *Hypericum perforatum* L. is an important kind of herbs which its Iranian species characterized by high percentage of Hyperisin as the most important substance of its leaves and flowers. It has an important role in curing some of diseases. In this research, the energy consumption and special required energy for drying of *Hypericum perforatum L.* were investigated by using hot air drying method. The experiments were done at four levels of the temperature (40, 50, 60 and 70°C), air velocity at three levels (0.3, 0.7 and 1 m/s) and bed depth at three levels (1, 2 and 3 cm) on factorial experiment design based on completely randomized design with three replications. Based on results with increasing of temperature, air velocity and bed depth, energy consumption was increased. On the other hand, in constant temperature, with increasing of air velocity special required energy was increased but in constant air velocity, with increasing of temperature, increased.

[Hossein AhmadiChenarbon, Saeid Minaei, Akbar Arabhosseini, Ali Motevali. Evaluation of energy consumption and special energy required for drying of *Hypericum perforatum L.*. Journal of American Science 2011;7(5):969-]. (ISSN: 1545-1003). http://www.americanscience.org.

Key words: *Hypericum perforatum* L., energy consumption, special required energy

1. Introduction

Drying action by which water activity due to a food remove almost all the water in which there will stop. The main purpose of drying is increasing the storage period, weight, volume of material (for packing and transportation) and preventing biological activities such as microbial and enzyme (Koyuncu et al., 2007). During storage of agricultural products depend on two physical factors of temperature and moisture. With decreasing temperature or humidity or both can be significantly increased during this period. Factors affecting the time and energy consumption during the drying process are: 1-physical properties of product 2-The geometric shape 3-Relative humidity 4-Temperature (Air Products) 5- Equilibrium moisture content 6-Initial moisture content of the product 7-Original compositions. Each of the above mentioned factors have a direct effect on the speed, and rate energy consumption during the drying process (Aghbashlo et al., 2008). Akpynar (2004) studied the energy required for drying sheets of red peppers. He reported that with increasing temperature, the ratio of energy consumption will increase, but over time these indices decreased gain (Akpinar, 2004). In another study, during drying pomegranate seeds with a thin layer of dry warm air velocity drying time, energy consumption and specific energy requirements decreased with increasing temperature (Aghbashlo et al., 2008). Nowadays most developed countries have done more studies on plant flora of their country and identify medicinal plants used in other countries. The major issue over the way such research has been extensive studies on factors herbs are used, the issue of recognition and preservation of active ingredients in plants, especially medicinal plants are different forms. The main reasons for short approach to medicinal plants are: 1- Side effects because of using synthetic drugs 2- Lack of affordable drugs, making some synthetic 3 - Exclusive treatment of some diseases with medicinal plants such as leprosy, leishmania and said Vitiligo Herbal treatments are only to be fourth - despite the valuable clinical experiences. One of the most useful medicinal herbs is St. John's Wort (*Hypericum perforatum* L). The property of the Iranian species of this crop is high level of Hypericin as the most important essential oil of its flower and leaves which plays an important role in the medical treatment of various diseases. Its annual trade level has been $ 210 m in USA and $ 570 m throughout the world (Sirvent et al., 2002). On the other hand this herb farm developed in Western Europe, for example in Germany the level of production during 1992 to 1997 is twenty times (Buter et al., 1998). The purpose of this study is to determine energy consumption and the specific energy during the drying process of *Hypericum perforatum* L.

2. Materials and methods

2.1. Drying equipment

Three Kiln type laboratory dryers were utilized to conduct the drying experiments. Drying chamber is a 40×40×50 cm container located 70cm above the heating elements (Figure1).Each dryer has two electric elements to generate the required heat, one of them controlled by a digital thermostat and the other controlled manually. Hot air flow is produced by a blower located under the elements, providing an adjustable flow rate in the range of 180 to 220 m^3/h using a dimmer. Two sensors are mounted in the upper and lower parts of the dryer to measure the temperature of the drying air before and after the samples location.

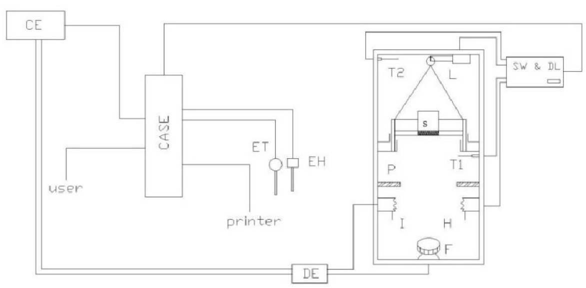

Figure1 Experimental dryer
(F) fan, (H) heat generator, (S) sample, (T_1) Lower thermometer, (T_2)Upper thermometer, (Sw) switches, (DL) data logger, (CE) control electronic system, (DE) electronic driver, (EH) environment relative humidity sensor, (ET) environment temperature sensor

Prior to starting of each experiment, air temperature was adjusted by the thermostat and the dryers were activated to reach the required temperature. Data collection for thin layer drying experiments was performed through weighing of samples at 5min intervals using a ±0.00lg digital balance (Sartorius, model PT210, Germany) .The mean value of the sample dry weight was used for calculations. Weighing of the samples continued until three consecutive readings showed the same value. Initial and final sample moisture contents were determined gravimetrically before and after the drying experiment. Moisture content of the samples was determined by drying in a vacuum dryer (model Galen Kamp) at 70ºC, 150 mbar, for 8hours (Tsami et al., 1990). The velocity of drying air was adjusted to the desired level by adjusting the blower motor and measured by an anemometer (AM- 4201, Lutron) with an accuracy of ±0.lm/s. During the experiments the ambient air temperature and RH variations in the laboratory were measured to be between 25 to 29ºC and 31- 33%, respectively. Given the small size of the samples, 35 by 35 cm metal micro-pore meshes were used as tray to keep the samples in the dryers. Aluminum frames of 35 by 35 cm cross section with 1, 2 and 3cm height were placed on the porous plates to obtain the desired bed depths. The samples were placed in the frame while a metal mesh was used on the frame to avoid any sample skip by air current flowing.

2.2. Drying process

Samples of St. John's wort were obtained from the Medicinal Herb Research collection of Jahad-e-Daneshgahi in May and June, 2009. The plants were harvested just before flowering and the leaves were immediately removed from the stems. The leaves were cut and stored separately in plastic bags and refrigerated at temperature of 4±1ºC to prevent microbial activity. Moisture content of the leaves was found to be 61% db. In this study, the independent variables were drying temperature at 40, 50, 60, and 70ºC, air velocity at 0.3, 0.7, and 1 m/s and bed depth at 1, 2, and 3cm levels. Thus, there were 36 treatments replicated three times. Dependent variable was drying time needed to determine the proper model for thin layer drying of St. John's wort leaves. A factorial experiment design was laid out in completely randomized design with three replications. All data were subjected to analysis of variance and Duncan's multiple range test was used to compare the treatment means.

2.3. Consumed energy in every drying period

Total consumed energy (E_t) in every drying period is calculated from the sum of 1 and 4 relationships (Koyuncu et al., 2007).

$$E_a = A\ V\ \rho_a\ C_a\ \Delta t\ \Delta T \qquad (1)$$

Where:

E_a: total consumed energy in every drying period (kW.h), V: air velocity (m/s), A: Area on which the experimental sample put (m^2), ρ_a: air density (kg/m^3), Δt : total drying time of each sample (h), ΔT : the difference between drying temperature and ambient temperature (°C), C_a: air specific heat (kJ/kg°C)

Equation (2) was used to calculate air specific heat (Brooker et al., 1992).

$$C_a = 1.88\ \omega + 1.004 \qquad (2)$$

Where:

ω: humidity ratio. Relative humidity is converted to humidity ratio with equation of 3(Brooker et al., 1992).

$$\omega = 0.662\ [\varphi p_{vs} / (p - \varphi p_{vs})] \qquad (3)$$

Where:

P: air pressure (kPa), φ: relative humidity, P_{vs}: saturated vapour pressure (kPa).

Also required evaporation energy is obtained through equation (4) (Brooker et al., 1992).

$$Q = h_{fg}\ (m_w) \qquad (4)$$

Where:

Q: evaporation energy (kJ), h_{fg}: hidden evaporation heat (kJ/kg), m_w: water mass transferred to the air (kg)

2.4. Calculation of specific energy

Specific energy is the energy value required for drying 1kg of fresh product. Equity (5) was used for calculation of specific energy (Brooker et al., 1992):

$$E_s=E_t/W_o \quad (5)$$

Where:

E_s: required specific energy (kWh/kg), W_o: sample original weight (kg)

The experiment was performed as a factorial completely randomized design with three replications and Duncan's multiple range test was used to compare the treatment means by MSTATAC software.

3. Results and discussion

3.1. Energy consumption during drying

The result of analysis of variance of data obtained from the effect of three parameters, air velocity, bed depth and temperature on energy consumption based on factorial experiment with completely randomized design are presented in table 1. The effect of the said parameters on energy consumption is significant at α=1%.

Table 1 Analysis of variance of data obtained from the effect of three parameters, air velocity, bed depth and temperature on energy consumption

Variable	df	SS	MS	F
Replication	2	642.56	321.28	3.42 *
Temperature	3	9820.15	3273.38	34.90**
Air velocity	2	12542.11	6271.05	66.86**
Temperature ×Air velocity	6	2463.69	410.61	4.37**
Bed depth	2	3479.58	1739.79	18.55**
Temperature ×Bed depth	6	1975.27	329.21	3.51**
Air velocity ×Bed depth	4	1542.41	385.60	4.11**
Temperature ×Air velocity ×Bed depth	12	1024.23	85.35	0.91 ns
Error	70	6564.78	93.78	

**Significant difference (α=1%), *Significant difference(α=5%), ns: No significant difference

Means comparison of the effects of different drying treatments on energy consumption at α =1% is shown at tables 2-4.

Table 2 Means comparison of energy consumption resulting from the interplay of temperature and air velocity

	Temperature(°C)			
Air velocity (m/s)	40	50	60	70
0.3	3.58^b	3.42^b	2.14^a	1.98^a
0.7	9.90^h	9.22^g	5.45^e	4.86^c
1	14.38^j	13.12^i	6.04^f	5.06^d

Table 3 Means comparison of energy consumption resulting from interactive effect of temperature and bed depth

	Temperature(°C)			
Bed depth(cm)	40	50	60	70
1	8.61^g	7.63 ^f	2.30^b	1.86 ^a
2	9.38^h	8.63 ^g	5.17^d	4.40 ^c
3	9.78^i	9.51 ^hi	6.16^e	5.27 ^d

Table 4 Means comparison of energy consumption resulting from interactive effect of bed depth and air velocity

	Bed depth(cm)		
Air velocity (m/s)	**1**	**2**	**3**
0.3	1.92[a]	3.04[bc]	3.39[c]
0.7	2.7[b]	7.88[d]	8.73[e]
1	7.91[d]	9.77[f]	10.99[g]

Results show that as temperature as well as hot air velocity increase, drying time decreases due to increase in temperature gradient and consequently increase in velocity of evaporation of product humidity. The cause of this is that as air velocity increases, ambient vapor pressure decreases and consequently the humidity of the product faces with less resistance for exiting and evaporate quickly. On the other hand increase in temperature and the air velocity causes an increase in enthalpy of the incoming air, this in turn causes an increase in transfer of mass and warmth and consequently energy consumption. Other researchers obtained similar results in their observations (Aghbashlo et al., 2008; Koyuncu et al., 2007). As the diameter of the product layer in the dryer increased, the time and energy required for drying increased so that increasing the diameter of product layer resulted in an increase in the energy required for drying.

3.2. Specific energy during drying process

As described earlier specific energy is the amount of energy required for drying a given weight of the fresh product. Based on performed measurements, weight of the fresh plant for the depths of 1, 2 and 3cm equaled to 0.222, 0.364 and 0.510 kg respectively. In this regard, the specific energy was calculated by division of the consumed energy for each depth on the respected plant weight. The results of analysis of variance of the data obtained from the effect of three parameters, air velocity, bed depth and temperature on the specific energy are presented at table 5. Results show that the effect of each element and their interactive effects on the specific energy are significant at α=1%.

Table 5 Analysis of variance of the data obtained from three parameters, air velocity, bed depth and temperature on the specific energy.

Variable	df	SS	MS	F
Replication	2	892.43	446.21	3.91 *
Temperature	3	10254.14	3418.04	29.96**
Air velocity	2	15263.23	7631.61	66.90**
Temperature ×Air velocity	6	4542.54	757.09	6.63**
Bed depth	2	5423.64	2711.82	23.77**
Temperature ×Bed depth	6	2519.34	419.89	3.68**
Air velocity ×Bed depth	4	2467.64	616.91	5.40**
Temperature ×Air velocity ×Bed depth	12	2415.87	205.32	1.76 ns
Error	70	7985.51	114.07	

**Significant difference (α=1%), * Significant difference (α=5%), ns: No significant difference

Means comparison of the effect of different drying treatments on the specific energy at α=1% is shown at table 6-8.

Table 6 Means comparison of specific energy resulting from the interplay of temperature and air velocity

	Temperature(°C)			
Air velocity (m/s)	**40**	**50**	**60**	**70**
0.3	10.71[d]	10.08[c]	5.86[b]	5.43[a]
0.7	25.56[j]	23.12[i]	10.9[g]	9.49[f]
1	30.73[i]	25.60[k]	16.31[h]	12.29[e]

Table 7 Means comparison of specific energy resulting from interactive effect of temperature and bed depth

	Temperature(°C)			
Bed depth(cm)	**40**	**50**	**60**	**70**
1	38.47[j]	33.04[i]	9.39[d]	7.39[c]
2	21.26[h]	19.2[g]	9.66[d]	7.59 [c]
3	13.28[f]	912.57[e]	6.01[b]	4.24[a]

Table 8 Mean comparison of specific energy resulting from interactive effect of bed depth and air velocity

	Bed depth(cm)		
Air velocity (m/s)	**1**	**2**	**3**
0.3	7.66[c]	3.84[b]	1.56[a]
0.7	23.64[h]	17.12[f]	11.05[d]
1	33.91[i]	21.33[g]	14.48[e]

Results showed that in constant temperature as air velocity increased, specific energy increased too. However in constant air velocity as temperature increased specific energy decreased. Based on tables 6-8 the least and the most specific energy required for drying *Hypericum perforatum* L. at the diameter of 1cm and at different air temperatures and velocities averaged 36.19 and 7.52 (kW.h/kg) respectively, at the diameter of 3cm averaged 13.88 and 2.9 kw.h/kg. The specific energy required for drying the said herb decreased due to an increase in the diameter of product layer from 1-2 and 2-3 so that in constant air velocity and temperature, the most specific energy required for the drying process was related to the diameter of 1cm. The cause is that as diameter increases so does the weight of the product in the dryer. Similar results have been reported by other authors (Aghbashlo et al., 2008; Koyuncu et al., 2007).

4. Conclusion

In this study was dealt with drying *Hypericum perforatum* L. results were obtained: 1- The amount of consumed energy was decreased by increasing temperature and was increased by increasing air rate and thickness of product layer in the dryer. 2- The amount of required specific energy was decreased by increasing temperature and thickness of product layer and was increased by increasing air rate.

Acknowledgement

Financial support from Islamic Azad University, Varamin Pishva Branch (Iran) is gratefully acknowledged.

2011/13/5

Corresponding Author:
Dr. Hossein Ahmadi Chenarbon.Department of Agriculture, Varamin Pishva Branch, Islamic Azad University – Varamin Pishva - Iran . E-mail**:** h.ahmadi@iauvaramin.ac.ir

References

1. Aghbashlo M, Kianmehr M, Samimi-Akhhijahani H. Influence of drying conditions on the effective moisture diffusivity, energy of activation and energy consumption during the thin – layer drying of berberis fruit (Berberidaceae). Energy Conversion and Management 2008; 49:2865-2871.
2. Akpinar EK. Energy and exergy analysis of drying of red pepper slice in convection type drier. International Journal of Heat and Mass Transfer 2004; 31(8): 1165-1176.
3. Brooker DB, Baker-Arkema FW, Hal CW. Drying and Storage of Grain and Oil seeds. 1992.Van Nostrand Reinhold, New York.
4. Buter B, Orlacchio C, Soldati A, Berger K. Significance of genetic and environmental aspects in the field cultivation of *Hypericum perforatum* L.. Journal of Planta Medica 1998; 64: 431- 437.
5. Koyuncu T, Pinar Y, Lule F. Convective drying characteristics of azarole red and yellow fruits. Journal of Food Engineering 2007; 15: 258-265.
6. Sirvent T M, Walker L, Vance N, Gibson DM. Variation in hypericins from wild populations of *Hypericum perforatum* L. In the Pacific Northwest of the U.S.A. Economic Botany 2002;56:41- 48.
7. Tsami E, Maroulis ZB, Morunos-Kouris D, Saravacos GD. Heat of sorption of water in dried fruits. International Food Science Technology 1990;25:350-359.