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Development of A Rotary Drum Dryer to Dry Medicinal and Aromatic Plants

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Abstract: The secondary metabolites of medicinal and aromatic plants show beneficial biological activities (antioxidant, antimicrobial, antidepressant, etc.). Drying is the most common process to decrease the high moisture content of the fresh plant materials to the safe storage final moisture content. Relatively low temperature drying of medicinal and aromatic plants limits the dryer capacity. There is a scientific/technological motivation to develop prototype dryers to accelerate the drying process and to maintain product quality of medicinal and aromatic plants. This article presents the preliminary results of a compressive research project being currently conducted at Gaziosmanpaşa University, Turkey. This project aims to develop/measure the effectiveness of two different prototype dryers including the rotary drum dryer to dry medicinal and aromatic plants in terms of reducing specific drying energy consumption, keeping product quality and accelerating drying process. Chopped spearmint plants were successfully dried in the rotary drum drier which was adjusted to give 40 °C hot air. However, some improvements are needed to increase product quality (color in this paper) and reduce drying time/specific energy consumption. One of possible improvements is to stop drying process as soon as leaves reach to the final moisture content without waiting for the completion of branches' drying. The second possible improvement is to use different temperature profiles. The Page equation was satisfactorily fitted to the drying curve.
Key words: Medicinal plants, Aromatic plants, Drying kinetics, Rotary drum dryer

INTRODUCTION

Medicinal and aromatic plants have various secondary metabolites showing biological activities beneficial to human health and welfare. Therefore, several products obtained from medicinal and aromatic plants have already become important commercial commodities as tea, perfume, cosmetic materials, drugs, natural dyes, insect repellent and disinfectant since ancient times (Baydar,2005). Their high initial moisture content(~ 80 % wb) must be immediately reduced to the safe storage moisture content (~10 % wb) to eliminate microbial and self-biochemical deterioration reactions after harvest. Drying is the most common method for the postharvest preservation of medicinal and aromatic plants since it allows for the quick conservation of those secondary metabolites in an uncomplicated manner (Müller, 2007). The drying time is comparably long and energy efficiency is low since low drying temperatures ranging 30 to 50 °C are recommended to preserve the active plant components (Müller, 2007). Therefore, the energy demand of drying these plants represents a significant cost factor that represents 30-50% of the total costs in medicinal and aromatic plant production (Müller, 2007). New dryers should be developed and their optimum operating conditions should also be determined to get high quality products from medicinal and aromatic plants.

The present paper contains preliminary results of a comprehensive research project being currently conducted at Gaziosmanpaşa University, Turkey and financially supported by The Scientific and Technological Research Council of Turkey. The aim of this research is to develop two different new dryers including the rotary drum dryer to dry medicinal and aromatic plants fast and at high quality with minimum energy cost.

MATERIALS and METHODS

Drying Material

Fresh mint plants were grown and harvested in the experimentation fields belonging to Faculty of

Agriculture, Gaziosmanpasa University, Tokat (Turkey). They were chopped to 5 cm long pieces to accelerate drying and handling. Their average initial moisture content was determined to be 77,3 % (wet base) by oven drying at 105 ˚C for 24 hrs.

Rotary Drum Dryer

A new rotary drum dryer was designed and manufactured in this research study (Figure 1). This rotary drum dryer has a cylindrical drum, 95 cm in outer diameter and 130 cm in length. The drum was made of 1 mm thick perforated chrome-nickel sheet having the holes of 2 mm diameter. Four 30 cm wide wings were placed longwise inside this drum at 90° angles away from each other to mix drying materials (Figure 2). The drum was placed on the four rubber wheels and its bottom was faced to the air distribution room. One of the rubber wheel was powered by an electrical motor to turn the drum counterclockwise at 1 min^{-1} rotation (Figure 3). The fresh air was sent by a fan to the electrical resistant heater. The air heated up to the desired temperature was forced to the bottom of the drum through the connection pipe of 25 cm diameter and the air distribution room enclosing 1/3 part of the drum. . The air was passed through the drum while gaining the moisture from the drying material. The materials to be dried was placed into the drum by hand after detaching the drum door. The drum door was closed after each loading. The rotation speed of fan and the rotation speed of drum can be separately adjusted by electronic variators. The fan speed was adjusted to supply air at average 500 $m^3 \cdot h^{-1}$ volumetric flowrate. To find the volumetric flowrate of heated air, its speed of was measured by an electronic hot-wire anemometer(Testo 425, Germany) in the connection pipe just before the air distribution room. The temperature of heat air was sensed by a Pt100 temperature sensor and the signal was transferred to the electronic control unit (Elimko 210, Turkey) adjusting the electrical energy amount to the heater.

Drying Experiments

15 kg newly-harvested fresh spearmint plant (*Mentha spicata* L.) pieces were loaded to the rotary drum dryer. The drying air temperature was set to 40 ˚C. Only the rotation of the drum was temporarly stopped and two 50 g samples were immediately taken to determine their moisture contents at every 1.5 hrs time intervals until reaching the final moisture content (9-11 %). The total electrical energy consumption was measured by Network analyzer (Entes MPR63, Turkey). The temperature and relative humidity of ambient air and heated air just after the heater were measured by the sensors (HOBO S-THB-M008, ONSET, USA) every 10 minutes and stored by the data logger (HOBO H21-002, ONSET, USA). In addition, the temperature and relative humidity of drying air in the centre of the drum and at the outer top of the drum were measured and stored at every 10 minutes.

Data Processing and Mathematical Modeling

Sosyal and Öztekin (2001) reported the specific heat energy consumption and the specific electrical energy consumption, separately since they used LPG burner to heat air for their dryer. In this current study, they were combined and named specific energy consumption. In addition, the specific energy consumption was calculated based on two separate approaches.

Figure 1. Rotary drum dryer.

Figure 2. Inner wings of drum and pipe for temperature/RH sensor

The first approach did not considered the temperature rise of drying air after heating. It was calculated as follows:

$$SEC_1 = \frac{TEC}{AWR} \quad (1)$$

In the preceding equation;

SEC_1 : Specific energy consumption without considering temperature rise (kWh·kg water^{-1})

TEC : Total energy consumption (kWh)

AWR : Amount of water removed from the drying material (kg).

The second approach considered the temperature rise of drying air after heating. It was calculated as follows;

$$SEC_2 = \frac{TEC}{AWR \cdot (T_{ha} - T_{aa})} \quad (2)$$

SEC_2 : Specific energy consumption with considering temperature rise (kWh·kg water^{-1}·°C^{-1})

TEC : Total energy consumption (kWh)

AWR : Amount of water removed from the drying material (kg)

T_{ha}: The average temperature of heated air (°C)

T_{ha}: The average temperature of ambient air (°C)

The second approach eliminates the effect of the differences in the ambient air temperatures where the drying experiments are conducted.

The amount of water removed from the drying material was calculated as follows:

$$\Delta W = W \cdot \frac{N_1 - N_2}{100 - N_2} \quad (3)$$

In the preceding equation;

N_1 : Initial moisture content of drying material (% wb)

N_2 : Initial moisture content of drying material (% wb)

W : The amount of wet material to be dried (kg)

The drying kinetics relates the moisture ratio to the drying time. The moisture ratio is formulized as follows:

$$MR = \frac{M - M_e}{M_0 - M_e} \quad (4)$$

In the preceding equation;

M: Moisture content of drying material at any sampling time (% db)

M_e: The equilibrium moisture content of drying material based on drying conditions

M_0: Initial moisture content of drying material at any sampling time (% db)

The values of the equilibrium moisture content, M_e, are relatively small compared to M and M_0. Thus, moisture ratio can be calculated as follows (Doymaz and Pala, 2002):

$$MR = \frac{M}{M_0} \quad (5)$$

Many empirical equations are given in the literature to describe thin layer drying kinetics of agricultural and food materials. One equation that has been widely used in thin layer drying studies is Page's equation (Doymaz and Pala, 2002; Doymaz, 2007). Page's equation was written below;

$$MR = \exp\left(-k \cdot t^m\right) \quad (6)$$

In the preceding equation, k and m are model parameters whose values are estimated from the experimental data. The value estimation of model parameters and the model variance analysis were performed by SigmaPlot software.

Color Analysis

The colors of both fresh and dehydrated spearmint plants were quantified by using a Minolta

(CR-400) Chromameter (Japan). Five color measurements were done for each treatment. This method gives numeric values of three chromatic scales (L*, a*, b*). L is the brightness ranging from no reflection for black (L* = 0) to perfect diffuse reflection for white (L* =100) . The value "a*" is the redness ranging from negative values for green to positive values for red. The value "b*" is the yellowness ranging from negative values for blue and positive values for yellow. The color at the grid origin (a* = 0 and b*= 0) is achromatic (gray) (McGuire, 1992). McGuire (1992) stated that color scales (L, a and b) do not provide an indication of hue and chroma aspects of color which are intuitively understood by those in the marketing chain from producer to consumer. Furthermore, McGuire (1992) recommended to use hue angle (h^o) and chroma (C) as more practical measures of color. Hue angle is defined as a color wheel, with red-purple at an angle of 0^o and 360^o, yellow at 90^o, bluish-green at 180^o and blue at 270^o. On the other hand, Chroma (C) represents color saturation which varies dull at low chroma values to vivid color at high chroma values. There are two more derived color measures used in the literature. One of them is the total color change parameter (ΔE) (Maskan, 2001). The second derived parameter is Browning index (BI). Browning index represents the purity of brown color and is considered as an important parameter associated with browning (Palou *et al.*, 1999). The chroma, hue angle, the total color change parameter and browning index were calculated by using the equations given in the literature.

RESULTS and DISCUSSION

The temperature and relative humidity values of air at four different locations during drying process were given in the Figures 3 and 4, respectively. The average temperature and relative humidity values of ambient air were 22.5 °C and 46 %, respectively. The average temperature and relative humidity values of heated air were 40.5 °C and 17.2 %, respectively. The temperature control system of electrical heater kept the temperature of heated air close to the prescribed temperature (40 °C). The heater increased the temperature of ambient air by 18 °C.

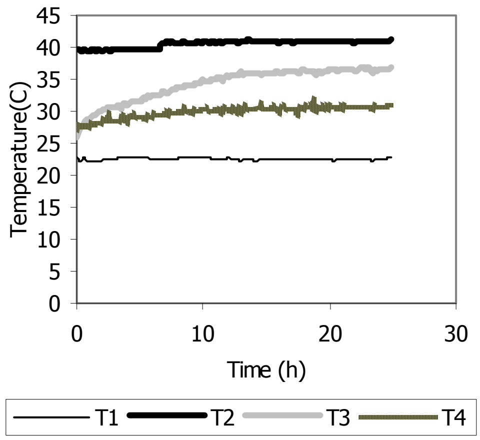

Figure 3. The temperature values of ambient air (T1), heated air just after the heater (T2), the air passing through the centre of drum (T3) and the air passing through the outer top of drum (T4).

The average temperature and relative humidity values of the air passing through the centre of drum were 34.3 °C and 27 %, respectively. The average temperature and relative humidity values of the air passing through the outer top of drum were 29.8 °C and 30.3 %, respectively. The temperature of drying air decreased as the relative humidity of drying air increased as a result of gaining moisture form drying material. The reason for the lower temperature of air passing through the outer top of drum than the temperature of air passing the centre of drum may be that the drum cooled the air together with the moisture and plants residing on it. The mixing of ambient air with drying air was not expected since the sensor was located very close to the drum. As seen in Figure 3, the temperature values of ambient air and heated air stayed almost constant during drying while the temperature values of air passing through the centre of drum and the outer top drum steadily increased because of the moisture gain from the drying material decreased as supported by the changes in the relative humidity values in Figure 4.

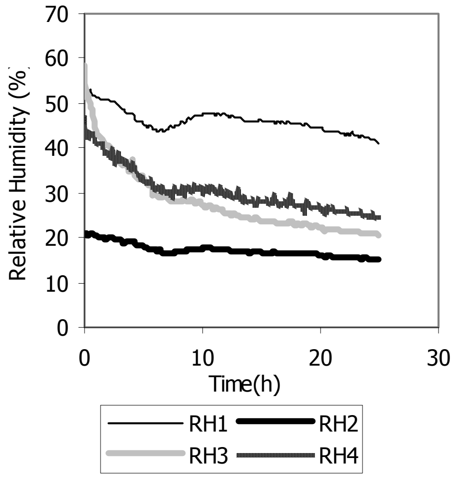

Figure 4. The relative humidity values of ambient air (RH1), heated air just after the heater (RH2), the air passing through the centre of drum (RH3) and the air passing through the outer top of drum (RH4).

The relative humidity of heated air stayed relatively constant while the relative humidity values of air passing through the centre of drum and the outer top of drum decreased during drying process. The relative humidity values of air passing through the outer top of drum were constantly higher than the relative humidity values of air passing through the centre of drum. These results comply with the differences in their temperature values explained previously. These results show that the volumetric flow rate of drying air can be reduced below 500 $m^3 \cdot h^{-1}$ since the air leaving the dryer still have high moisture deficiency. The airflow rate of drying air can be gradually reduced to keep the relative humidity of air leaving the dryer constant.

The mint plants were dried until reaching the final moisture content of 9 % (wb) from the initial moisture content of 77.3 % (wb) in 25.5 hours. The leaves of mint plant dried much faster than the mint branches based on the authors' observation . But, the drying process was continued until the mint branches were also dried. The calculated and predicted moisture ratio values over time during the drying experiments were plotted in Figure 5.

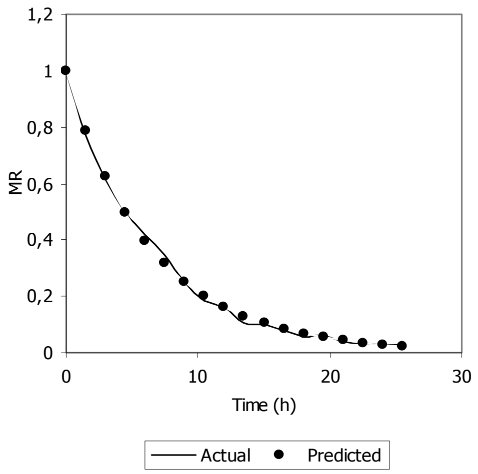

Figure 5. The actual and predicted values of Moisture Ratio of Spearmint over time during drying process.

The page equation represented the experimental data very well (R^2=0.9980). The numerical values of k and m parameters of Page equation were estimated to be 0,1607 and 0,9764, respectively. Doymaz (2006) dried only mint leaves in 10 hrs at 35 °C and less than 5 hrs at 45 °C. These results show that the leaves and branches of mint plants must be separated or the drying process must be halt and then the leaves and branches are separated when the leaves are dried. The first choice currently seems impractical at industrial scale since the leaves and branches of the spearmint plants strongly and complexly attach to themselves. The applicability of the second choice seems more plausible and are being currently investigated by the authors.

67.5 KWh electrical energy was consumed during the drying process. The Specific energy consumption without considering temperature rise was found to be 5.99 $kWh \cdot kg\ water^{-1}$. On the other hand, the Specific energy consumption with considering temperature rise 0.333 $kWh \cdot kg\ water^{-1} \cdot °C^{-1}$. Soysal and Öztekin (2001) found that the specific energy consumption including electrical energy consumption and heat energy consumption of mint drying ranged from 1.39 to 1.7 $kWh \cdot kg\ water^{-1}$. They dried mint until reaching the final moisture content of 14.5 % (wb) which is 5.5 points higher than the result (9%) of the current study. It is known that higher energy consumption rates are needed to remove one unit moisture from the drying materials at lower moisture contents. Therefore, a standard approach must be developed to compare the specific energy consumption results obtained from different dryers. This standard must have a fixed final moisture content and a correction factor for the difference in climatic conditions where drying research studies are done.

The color values (a*, b* and L*) of fresh mint plants were -11.42, 20.27 and 35.88, respectively. The chroma and hue angle values of fresh mint plants were calculated to be 23.26 and 119,4° ,respectively.

The color values (a*, b* and L*) of dried mint plants were 1.90, 8.66 and 18.32, respectively. The chroma and hue angle values of dried mint plants were calculated to be 8.87 and 77.65° ,respectively. The values of browning indices of fresh and dried spearmint samples were 49.95 and 69.76. This result indicates the occurrence of browning reactions during drying processes. The color change value (24.90) also supports this fact since its value is much higher than zero. Soysal (2000) also reported the occurrence of darkening during mint drying and darkening intensified with the magnitude of drying air temperature. The decrease of the drying air temperature and/or drying under oxygen free atmosphere may reduce darkening. The first option will be further investigated by the authors in addition to use of different drying air temperature profiles (steady increase from low temperature to high temperature, square wave shape temperature change profile).

CONCLUSIONS

Chopped spearmint plants were successfully dried in the rotary drum drier which was adjusted to give 40 °C hot air. However, some improvements are needed to increase product quality (color in this paper) and reduce drying time/specific energy consumption. One of possible improvements is to stop drying process as soon as leaves reach to the final moisture content without waiting for the completion of branches' drying. The second possible improvement is to use different temperature profiles. The page equation satisfactorily represented the drying curve.

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REFERENCES

Baydar, H. 2005. Tıbbi, Aromatik ve Keyf Bitkileri Bilimi ve Teknolojisi. Süleyman Demirel Üniversitesi, Yayın No:55.

Doymaz, İ. 2006. Thin-layer Drying Behavior of Mint Leaves. Journal of Food Engineering 74:370-375.

Doymaz, İ., M. Pala. 2002. Hot-air Drying Characteristics of Red Pepper. Journal of Food Engineering 55: 331-335.

Maskan, M. 2001. Kinetics of colour change of kiwifruits during hot air and microwave drying. Journal of Food Engineering 48, 169-175.

McGuire, R.G. 1992. Reporting of objective color measurements. HortScience 27, 1254-1255.

Müller, J. 2007 Convective Drying of Medicinal, Aromatic and Spice Plants: A Review. Stewart Postharvest Review. 4:2.

Palou, E., A. Lopez-Malo, G.V. Barbosa-Canovas, J. Welti-Chanes, B.G. Swanson, 1999. Polyphenoloxidase activity and color of blanced and high hydrostatic pressure treated banana puree. Journal of Food Science, 64, 42-45.

Soysal, Y. 2000. İşletme Ölçeğinde Çeşitli Tıbbi ve Aromatik Bitkilerin Kurutulmasına Yönelik Bir Araştırma. Doktora Tezi. Çukurova Üniversitesi, Fen Bilimleri Enstitüsü, Tarım Makinaları Anabilim Dalı.

Soysal, Y., S. Öztekin, 2001. Technical andEconomic Performance of a Tray Dryer for Medicinal and Aromatic Plants. J. Agric. Engng. Res. 79(1):73-79.