INFRASTRUKTURA I EKOLOGIA TERENÓW WIEJSKICH
INFRASTRUCTURE AND ECOLOGY OF RURAL AREAS

No IV/1/2017, POLISH ACADEMY OF SCIENCES, Cracow Branch, pp. 1291–1300
Commission of Technical Rural Infrastructure

DOI: http://dx.medra.org/10.14597/infraeco.2017.4.1.099

ENERGY AND COST ANALYSIS OF ROSE *ROSA DAMASCENA* DRIED BY HEAT PUMP DRYING SYSTEMS

Bekir Ansar, Davut Akbolat
Suleyman Demirel University

Abstract

Isparta rose is an agricultural product that provides world-wide awareness to our country, offering social and cultural aspects and touristic and economic contributions. Turkey and Bulgaria are two major countries that produce rose for economic return. Isparta rose (rose damascena) is a therapeutic fragrant flower used in aromatherapy applications besides oil production.

The aim of this study is to determine the energy and cost analysis of drying of rose (Rosa damascena). Additionally, the energy consumption and unit cost of screening and separation was determined. Experiments were carried out in the Yakaören Rose Oil Factory of Gülbirlik, which was established in the village of Yakaören in the center of Isparta province. Temperatures of 45oC and 55oC were chosen as drying temperature in the experiment. According to the results of the research, work capacity for temperatures of 45°C and 55°C were 0.32 kg×h-1 and 0.63 kg×h-1, respectively. Specific energy consumption (SEC) for the same temperatures were 2.48 kWh×kg-1 and 8.96 kWh×kg-1, respectively. Specific moisture extraction rates (SMER) were found to be 0.402 and 0.112 kg×kWh-1. The unit drying cost was for the two drying temperatures of 45 oC and 55 °C are 0.51 and 1.84 Turkish liras (TL), respectively. As a result; the work capacity, SEC, MER and unit drying cost at a temperature of 55 oC was found to be higher than the work capacity at a temperature of 45oC. However, SMER at 55oC was lower than drying at 45 oC temperature. For this reason, rose drying at a temperature of 45 degrees is advantageous in SEC, SMER and Unit Drying Cost compared to drying roses at 55 degrees.

Keywords: Isparta rose, rose drying, drying energy, drying cost, heat pump dryer.

INTRODUCTION

Rose production in the world is realized in Turkey, Bulgaria, South Russia and Morocco, with rose production mostly in Turkey and Bulgaria (Weiss, 1997). Rose cultivation in Turkey is concentrated within the Isparta province with a share of 90% total production. The most important end products are rose oil, rose oil solid (rose concrete), rose absolute, and rose water (Baydar *et al.,* 2005). Fresh rose flowers can be used as raw materials or as additives for food products such as jelly, Turkish delight, paste, etc. as a reflection of rose oil and its derivatives. Furthermore, drying of fresh rose flower can be performed for for market demands when the amount of production in the oil rose is high in Turkey. For this purpose, nearly 1 ton of rose flower is dried each year and these are exported to some European countries, mainly Germany and France (Baydar *et al.,* 2008). Because the roses are generally dried in the open area and on the sun, the quality of the products may decrease. Dried rose flowers are mostly used in dry flower arrangements, stand and window dressings, aromatic pillows, herbal tea making, aromatherapy and hydrotherapy. The most important problem in the production of dry roses has been reported as the change of the smell intensity and the quality. Rose drying in the open air leads to many problems in terms of hygiene and product quality depending on the atmospheric properties. This problem can be solved only by drying with artificial drying methods. The heat pump drying system is one of them. Heat pump drying technology is energy efficient system due to low energy consumption and also it is environmentally friendly system due to low emission of gases and fumes into the atmosphere. Heat pump dryer is consisted of two engineering systems: the heat pump and the dryer. Heat pump assisted-drying provides a controllable drying environment for better products quality at low energy consumption (Prasertsan and Saensaby, 1998). The most important advantage of heat pump dryers over other dryers is energy efficiency (Chua *et al.,* 2002). The improvement in heat recovery results in lower energy consumption per unit of water removed by high energy efficiency (Kudra and Mujumdar, 2002). Heat pump dryer can provide very wide drying conditions up to a temperature of – 20 °C to 100° C and a relative humidity of 15-80% (Chua *et al.,* 2002). At the end of the drying, sterile conditions can be achieved when the product is of equal quality (Kudra and Mujumdar, 2002). Kiwi fruit was dried in a solar-powered and heat-pumped dryer and experimentally investigated. Drying air temperatures and air velocities were used 35^{o}C, 40^{o}C, 45^{o}C and 50^{o}C and 0.1-1.0 m$\times$s^{-1} respectively. At the end of the study, the optimum drying air temperature was found as 50^{o}C (Aktaş ve Kara, 2013). In another study, the effects of tray dryer, heat pump dryer, freeze dryer and microwave dryer techniques on apple slices of quality characteristics and energy efficiency were investigated. According to the results, the lowest SEC and highest SMER and MER values were obtained in the heat pump dryer (Baysal *et al.,* 2015). Four different products were dried using a closed loop heat pump drying system at 40°C drying air temperature, 1 m s^{-1} drying air speed and, 5 mm material thickness. According to the results, SMER was found for melon, apple, kiwi and banana as 0.332, 0.306, 0.303 and 0.232 kg$\times$kWh^{-1} respectively (Tunçkal *et al.,* 2016). When the sliced tomato was dried with heat pump drying system using 35^{o}C, 40^{o}C and 45^{o}C drying temperature, the drying rate increased with increasing temperature and SMER was found to be 0.324 kg$\times$kWh^{-1} for 45^{o}C (Coşkun *et al.,* 2016).

In this study, the energy efficiency, work capacity and cost analysis of the heat pump dryers in rose drying were determined. The work capacities and energy requirements of screening and separation systems were also determined.

MATERIAL AND METHODS

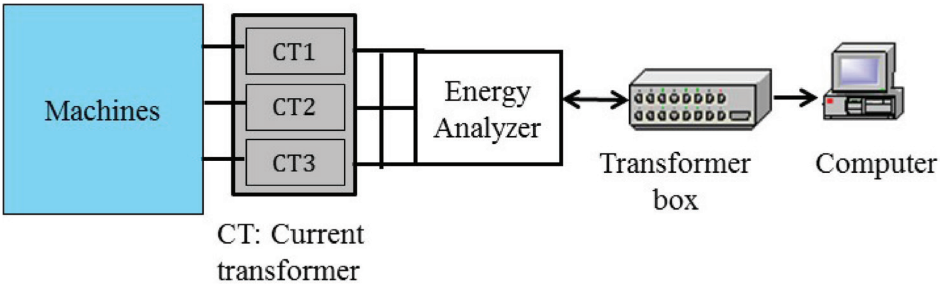
The trials of this study were carried out in the Yakaören Rose Oil Factory of Gülbirlik, which was established in the village of Yakaören in Isparta province of Turkey. This study was carried out in three stages. These steps are screening, separation, and drying. However, the rose materials used in these stages are independent of each other.

The screening system consists of three sieves with hole diameters of 10 mm, 20 mm and 30 mm and a motor with a 10-speed speed drive which generates vibration. At the end of the screening, there are 4 different groups of roses: <10 mm, 10 mm above, 20 mm above, 30 mm above. The energy consumption of the screening system was recorded before and during the experiment in one second intervals. Energy consumption was evaluated separately as idle, initial loading, actual loading and unloading. Work capacity, specific energy consumption and unit screening cost values of the screening system were calculated.

The airflow assisted separation system consists of a material supply band, a fan and an air duct. There is an adjustable opening to adjust the air flow at the fan outlet. The aim of the separation system is to separate the whole roses as sepal and petal. The energy consumption, revolution of fan and air velocity of air assisted separation system were measured before and during operation (table 1). Experiments were carried out by separated roses ranged above 20 mm and 30 mm sieve separated from screening system at air velocities of 7, 11, 16 and

18 m×s^{-1}. Work capacity, specific energy consumption and unit separation cost were determined for the air assisted separation system.

In the drying system experiments, energy consumption, air speed, humidity, temperature were recorded before and after the test. In addition to the heat pump, a heater has been used to raise the temperature from 45 to 55°C. 25 kg of coal containing 6200 kcal×kg^{-1} lower heating value was used in the heater. In the Electric Energy Monitoring System (EEMS), one power analyzer for each electric motor to be measured and three current transformers (CT) for each energy analyzer were used. Each energy analyzer, which has an EEMS, is connected to the computer where the data is recorded with the aid of the data transfer element set.



Source: Boyar (2006)

Figure 1. EEMS elements and wiring diagram

„CASE Pa300" type energy analyzers were used in the EEMS. It consists of RS485/RS232, RS232/serial port, serial port/USB interface elements that provide data transmission between energy analyzers and computer (Figure 1). EEMS was used in the screening, separation and drying processes.

The temperature and humidity measuring instrument were used to determine the temperature and relative humidity inside the cabinet where the drying experiments were carried out. The temperature/relative humidity measuring instrument (HOBO) has a temperature range of – 20 to 70°C and 25 to 95%, respectively. The rose moisture was determined by AND MX-50 model moisture detector at different stages of the experiments of fresh and dry rose.

The energy consumption, humidity and temperature of the drying system were determined at idle and loading positions before the tests. After the temperature inside the cabin reached the desired value, 2 kg of roses was loaded to each shelves and distributed evenly inside the shelves (Figure 2b).

Figure 2. Rose products in various stages (a – in garden, b – before drying, c – dried)

In the drying experiments, rose flower obtained from the local producers was used. The energy consumption of the system was continuously recorded at intervals of one second during the trials. The system's energy consumption was determined at the idle and loading stages.

Table 1. Measured quantities in drying system

Measurement time	Measured values				
	Moisture	Temperature (°C)	Energy consumption (kW)	Time (sec)	Rose amount (kg)
Before drying	-	X	X	X	-
In drying period	X	X	X	X	X

In order to determine the effectiveness of drying systems, the specific moisture extraction rate (SMER), the moisture extraction rate (MER) and specific energy consumption (SEC) were used. Additionally "unit drying cost" was used to evaluate the effectiveness of drying system (Baysal *et al*., 2015). These equations are below and were marked 1-4;

$$SMER = \left(\frac{\text{Amount of water removed during drying}}{\text{Total energy supplied in drying process}}\right), \frac{kg}{kWh} \quad (1)$$

$$MER = \left(\frac{\text{Amount of water removed during drying}}{\text{Drying time}}\right), \frac{kg}{h} \quad (2)$$

$$SEC = \left(\frac{\text{Total energy supplied in drying process}}{\text{Amount of water extraction during drying}}\right), \frac{kWh}{kg} \quad (3)$$

$$Unit\ drying\ cost = (Spesific\ energy\ consumption) \times (\text{Unit energy cost}),\ \frac{TL}{kg} \quad (4)$$

RESULTS AND DISCUSSION

The process of screening, separation and drying for the rose was done separately. For this reason, these processes were studied independently of each other. The work efficiency, specific energy consumption and unit cost of the screening system are given in Table 2.

Table 2. Results obtained from screening

Moisture ratio (%)	Work capacity ($kg \times h^{-1}$)	Specific energy consumption ($kWh \times ton^{-1}$)	Unit screening cost ($*TL \times ton^{-1}$)
70	371.50	0.57	0.117
75	376.82	0.56	0.115

(*) One Turkish Liras, TL= 0.275 US Dollar for April, 2017

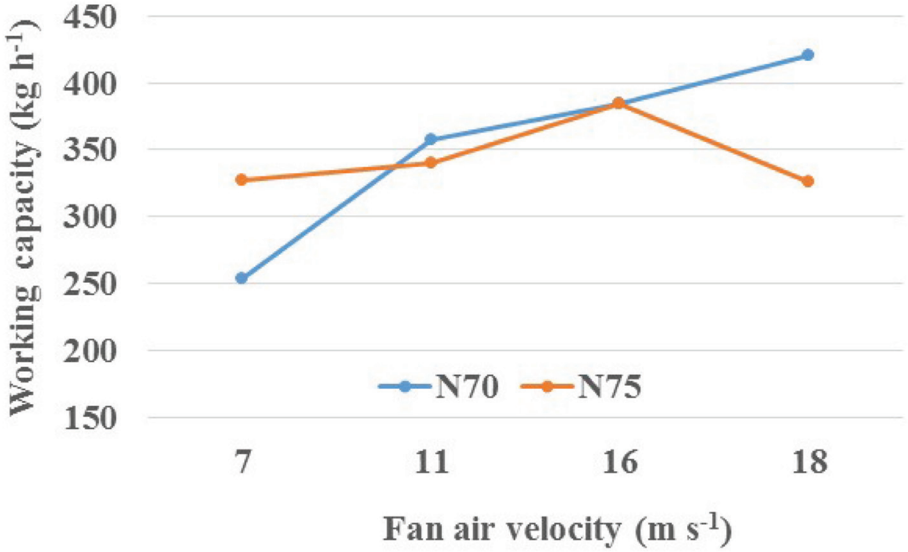


Figure 3. Relation between work efficiency and air velocity in the separation system

There was no significant difference between work capacity, specific energy consumption and unit screening costs, which were determined at two different moisture ratios (N) of (70% and 75%) as seen on the table. Since the energy consumption for the screening was very low and the cost of the work done was low at negligible level, the energy consumed in this section was not added to the drying energy cost.

Figure 3 shows work capacity as a function of air velocity of fan used in the separation system. As air velocity increased, the work capacity increased. However, there was no relationships between moisture content of rose and work capacity. It can be said that the work capacity of rose at low moisture content was found to be about 2.7% higher than the other points.

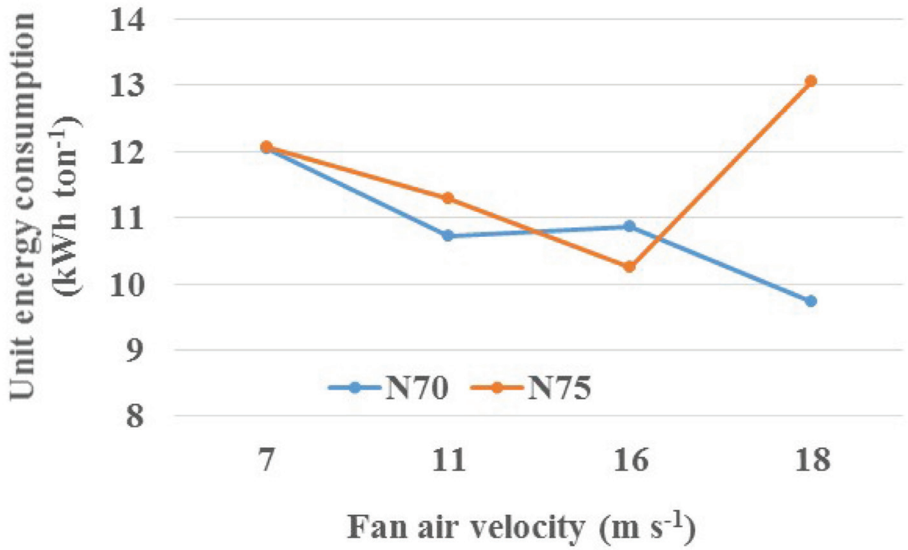


Figure 4. Relation between unit energy consumption and air velocity of separation system

By increasing the fan air velocity in the separator, the unit energy flux was reduced. However, it was not possible to establish a relationship between moisture content of rose and unit energy consumption. However, rose petals at 75% moisture had approximately 8% more energy consumption than rose petals at 70% moisture (Figure 4). The fan at high air speeds must be used to reduce the energy consumption in the separation system.

The moisture factor in the cost-enhancing elements has influenced energy consumption to a certain extent. As can be seen from the calculations made, it was found that the separation cost of rose at 75% moisture was approximately

7.6% higher than that of 70% (Figure 5). As the air velocity increased for both moisture ratios, the cost of unit separation was reduced. For this reason, the highest air speed should be selected to reduce the cost.

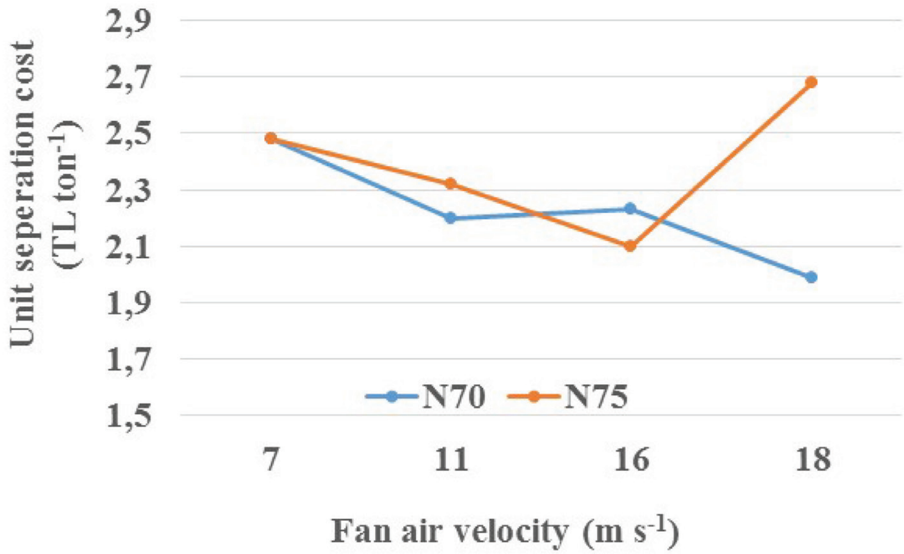


Figure 5. Relation between unit separation cost and air velocity of separation system

The results of the drying system in determining the work capacity, specific energy consumption, moisture extraction rate and unit drying cost in rose drying are given below (Table 3).

Table 3. The work capacity, specific energy consumption, moisture extraction rate and unit drying cost of a drying operating at two different drying temperatures

Drying temperature (°C)	Work capacity (kg×h^{-1})	SEC (kWh×kg^{-1})	SMER (kg×kWh^{-1})	MER (kg×h^{-1})	Unit drying cost (TL×kg^{-1})
45	0.32	2.488	0.402	1.347	0.51
55	0.63	8.96	0.112	2.372	1.84

Compared to the drying temperatures, the SMER at drying temperature of 45°C was higher than that of 55°C. However, the work capacity, SEC, MER, and unit drying cost at drying temperature of 55°C were higher than that of 45°C. The results suggest that drying at higher temperatures was more profitable and therefore preferred.

It was determined that the unit drying cost of rose from moisture 79.3 to 12.79% at drying temperature of 45°C was 0.51 TL×kg^{-1}. The work capacity of the dryer at drying temperature of 45°C was 0.32 kg dried rose per hour. It was found that the unit drying cost of rose from moisture 79.93 to 8.77% at drying temperature of 55°C was 1.84 TL×kg^{-1}. The work capacity of the dryer at drying temperature of 55°C was 0.63 kg dried rose per hour.

According to the labeling information of the motors of the drying system, the maximum power that can be drawn by the fan motor at the time of the load was reported as 1.5 kW and the compressor as 0.75 kW. When the system was operating at full load, the determined power was measured as 0.22 kW for the fan motor, 2.50 kW for the compressor and 0.68 kW for the drying system. When coal-fired additional heating was used to achieve a temperature of 45 to 55°C, the consumption of electrical energy in the drying system did not increase. However, until the additional heating system temperature reached to55°C, the heat pump drying system consumed 3.20 kW at 45°C and 3.37 kW at 55°C.

Kuzgunkaya (2006) reported that SMER ‘value of dried laurel leaf was 3.63 kWh×kg^{-1}. It was higher than the results we found for both temperatures. Prasertsan and Saen-saby (1998) found that SMER and MER values for mushroom drying were 0.540 and 2.71, respectively. Coşkun *et al.* (2016) reported that an average SMER value was found as 0.324 kg×kWh^{-1} in sliced tomato drying. Generally there is a difference in drying energy due to the properties of the dried products.

ACKNOWLEDGEMENT

I would like to thank Dr. Serkan Boyar for helping us during the execution of this research. We thank the SDU scientific research projects management unit for supporting the project numbered “SDU BAP 4107-Si-14”. Also, Thank to GÜLBİRLİK and ROSENSE for allowing us to use their establishment.

The data of this study were taken from the master’s thesis titled “Energy and cost analysis of screening, separation and heat pump drying system of Isparta rose”

REFERENCES

Aktaş, M., Kara, M. Ç. (2013). Güneş Enerjisi Ve Isı Pompalı Kurutucuda Dilimlenmiş Kivi Kurutulması. *Gazi Üniversitesi Mühendislik-Mimarlık Fakültesi Dergisi*, *28*(4). (in Turkish).

Baydar, H., Gokturk Baydar N., Debener T., (2005). Analysis of genetic relationships among rose damascene mill. Plants grown in Turkey by using AFLP and Microsatellite markers Turkey VI. Tarla Bitkileri Kongresi, 5-9 Eylül 2005, Antalya (Araştırma Sunusu Cilt II, Sayfa 1123-1126). (in Turkish).

Baydar, H., Kazaz, S., Erbaş, S., Örücü, Ö. K. (2008). Soğukta muhafaza ve kurutmanın yağ gülü çiçeklerinin uçucu yağ içeriği ve bileşimine etkileri. *SDÜ Ziraat Fakültesi Dergisi*, *3*(1), 42-48. (in Turkish).

Baysal, T., Ozbalta, N., Gokbulut, S., Capar, B., Tastan, O., Gurlek, G. (2015). Investigation of Effects of Various Drying Methods on the Quality Characteristics of Apple Slices and Energy Efficiency. *Journal of Thermal Science and Technology*, *35*(1), 135-144.

Boyar S. (2006). Karma Yem Sanayinde Enerji Verimliliğinin Belirlenmesi Ve İyileştirilme Olanakları Üzerine Bir Araştırma (İki Fabrika Örneğinde). Ege Üniversitesi Fen Bilimleri Enstitüsü, Doktora Tezi. 414s, İzmir. (in Turkish).

Coşkun, S., Doymaz, İ., Tunçkal, C., Erdoğan, S. (2016). Investigation of drying kinetics of tomato slices dried by using a closed loop heat pump dryer. *Heat and Mass Transfer*, 1-9.

Chua, K.J., Chou, S.K., Ho, J.C., Hawlader, M.N.A. (2002), Heat pump drying: recent developments and future trends, Drying Technology Volume 20.

Kudra, T., Mujumdar, A.S. (2002). Advanced Drying Technologies, Marcel Dekker, 249s. New York.

Prasertsan, S., Saen-Saby, P. (1998). Heat pump drying of agricultural materials. *Drying technology*, *16*(1-2), 235-250.

Tunçkal, C., Coşkun, S., Erdoğan, S. (2016). Kapalı döngü bir ısı pompalı kurutma sisteminin performans analizi. *Isi Bilimi ve Teknigi Dergisi/Journal of Thermal Science & Technology*, *36* (1). (in Turkish).

Weiss, E.A. (1997). Essential oil crops. In: Rosaceae. CAB International. Wallingford, Oxon, UK, pp. 393-416.

Bekir ANSAR
Corresponding author: Prof. Dr. Davut AKBOLAT

Suleyman Demirel University,
Agricultural Faculty,
Agricultural Machinery and Technologies
Engineering Department, 32260, ISPARTA
davutakbolat@sdu.edu.tr

Received: 12.04.2017
Accepted: 26.07.2017