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Performance Evaluation of Greenhouse Type Dryers for Red Pepper: Technical and Economic Aspect

B. Yelmen[1*], M. T. Çakir[2] and H. H. Şahin[3]

[1]Department of Wastewater Treatment, Adana Metropolitan Municipality, Water and Sewage Authority, Adana, 01120, Turkey.
[2]Department of Construction and Repair, Ankara, 06590, Turkey.
[3]Adana Metropolitan Municipality, 01120, Adana, Turkey.

Authors' contributions

This work was carried out in collaboration among all authors. Author BY designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors BY, HHS and MTC managed the analyses of the study and managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

In this study, the possibilities of drying the spices in Kahramanmaraş at the scale of the Red Pepper on a scale with plastic-covered high tunnel greenhouse type dryer were investigated. For this purpose, the red pepper was cut into two pieces, the seed house was removed and the shelves were placed in the vertical direction with 30 cm intervals in which the shelves were arranged at intervals of 2, 3, 4 and 5 kg / m^2 density of the shelves in the greenhouse were layered in thin layers. The drying was continued until a fifth of the mass of the material laid on the shelves was reduced. This time corresponds to the first five to six hours of drying. The ambient temperature rises to 55-65°C during the whole day. The products are dried in 26-27 hours in drying trials in first and second. Products which dried in the greenhouse have been exposed to approximately 2-4% more moisture loss than the products that are dried on a shelf 50 cm high from the ground. It has been determined that the optimum loading capacity can be increased to 187.5 kg in terms of technical

**Corresponding author: E-mail: byelmen@yahoo.com.tr;*

and economic performance criteria taken into consideration in the red pepper drying study carried out in 3 different periods. If the floor area and height of the plastic tunnel are evaluated effectively and furthermore, this figure will increase in a commercial tunnel of plastic. On the other hand, according to the results obtained in the first period with the optimum loading capacity calculated, it is determined that the plastic tunnel dryer can meet the first investment, operation and fixed expenses in a season and it is a profitable investment.

Keywords: Red pepper; drying; greenhouse type dryer; efficiency; economic performance.

1. INTRODUCTION

The production of spicy red pepper is especially concentrated in the Southeastern Anatolia Region of Turkey and the consumption is more in the domestic market [1]. The export of spicy red pepper is negligibly less because the product does not comply with the relevant norms in terms of food safety and quality. The first application is due to the high humidity (> 80%, w.b.) of the peppers, which are harvested manually from the field in spicy red pepper production; the material could be completely dried in the sun without pulling the handle. Due to the known negativity of disease and other crop pests such as red pepper, soil-moulded mould fungus, which has been dried on asphalt or soil ground for long years, it does not comply with food safety and quality norms. It is expected that the Southeastern Anatolia region is located in the sun zone and is advantageous in terms of sunbathing and that the drying season of agricultural products coincides with periods of intense solar energy, which will affect the use of this energy in drying [2]. On the other hand, the potential of solar energy available in the region during the summer months of the pepper harvest season makes it possible to make use of solar energy. In addition to the selection of the energy source as the sun, another important point is the drying place. On the other hand, the potential of solar energy in the region during the summer months of the pepper harvest season makes it possible to make use of solar energy. In addition to the selection of the energy source as the sun, another important point is the drying place. One of the drying systems that can be installed with local facilities used to obtain cleaner products at the producer level is the greenhouse gases. It is known that the researches carried out with the greenhouse type dryers in the literature are concentrated on the laboratory scale dryers due to the ease of application. The seedless grapes, green beans, sweet peppers and red pepper are dried by Tırıs et al. [3]. As a result of the comparison, they determined that the solar dryer reduces drying time and provides better product quality than traditional method. Fuller ve Charters [4], the plastic-covered tunnel type is used in a dry dryer. In this study, the researchers are calculated the drying performance between 15% and 17%. Arinze et al. [5], in their study, the aluminium absorber surface solar collector, plywood and polyethene material made of the drying room and insulated ducts used a dryer. It was determined that the sun drier was more advantageous than direct drying in the sun and natural gas drying systems, and the recycling period was one or two years. Augustus et al. [6], sunny dryers; classified as direct, indirect and combined dryers according to the contact of the solar radiation with the product to be dried. For the tomato collector area; 75% of the total crate area of the dryer, the drying airflow rate of 0.75 m^3 / day and the amount of product to be dried 4 kg / m^2 as a good drying property. Bala et al. [7], in their study, pineapples are dried in the tunnel type sunny drying system. The moisture content of the product at the end of drying is decreased from 87.32% to 14.13%. The efficiency of the tunnel dryer according to the results is calculated as 19% [8]. Farhat et al. [9], the greenhouse dryer that made of polyethene material tunnel type in pepper drying studies were used. They worked on the design taking into account the air velocity, temperature, indoor temperature and solar radiation. Moisture that is removed at the end of the drying process was found to be equal to 83% of the initial total mass. In a study by Gunel [10], a natural convection dryer with a solar air heater was used for drying of agricultural products. The efficiency of the dryer, its thermal performance and the quality of the product were investigated, the mass fraction and drying time and solar radiation relations were examined as exponential and polynomial relations. As a result of the data that is obtained from the experiments as a result of the natural drying without any pretreatment, the apricots that are subject to the sulfurization process, compared to apricots that are dried in the open exhibition mass loss of 9% to 13%, respectively. Koyuncu [11], who is designed by two different natural circulation greenhouse type product dryers, produced and tested their performance. It was observed that the efficiency of dryers was higher than drying in the open exhibition. The organic tomato drying experiments are performed under the ecological condition by Sacilik [12]. At the end of the drying, the humidity value of organic tomatoes decreased from the initial moisture of 93.35% to the last moisture level of 11.50%. At the end of the drying, the moisture content of organic tomatoes decreased from the initial moisture of 93.35% to the last moisture level of 11.50% [12]. In this study, a high-density dryer with polyethene high tunnel greenhouse was used to dry the spicy red pepper produced in Kahramanmaraş province.

2. MATERIALS AND METHODS

2.1 Materials

In this study, it is aimed to be dried the red pepper which is Sena type (*Capsicum annuum* L.) with a greenhouse type solar dryer within the province of Kahramanmaraş. Greenhouse is a high plastic tunnel type dryer module that is designed and manufactured for in drying process. The dimension of this structure is 8 x 6 x 2.86 m. and it is connected to the solar collector on the northern frontage. The heated air in this collector is sucked from the bottom to the greenhouse. A fan of Alfan brand (2007) with 0.98 x 0.95 m dimensions of 0.3675 kW and a maximum airflow of 8500 m^3 / h was installed to ensure this forced convection just above the high plastic tunnel entrance door. A fan was installed in Alfan brand (2007) with a maximum airflow rate of 8500 m^3 / h and a mass of 0.98 x 0.95 m on the high plastic tunnel entrance door. (Fig. 1).

The product was dried on top of racks in a drying tunnel located in the middle of the high plastic tunnel. The product was dried on shelves that positioned on top of a drying tunnel placed in the middle of the high plastic tunnel. For the drying process, 5 x 2.5 x 1 m shelves are placed on a roof with 0.30 m spacing in the vertical direction. (Fig. 2). Fresh material is dried on a plastic fly screen stretched to the shelf frame. In the open-air control drying experiments, thin-wire sieve-coated drying tables that are made of wood, 0.50 m in height and 2.50 x 1 m in height were used. The first Crimean red pepper was harvested in August and the second in September during the experiments that are performed in 2008.

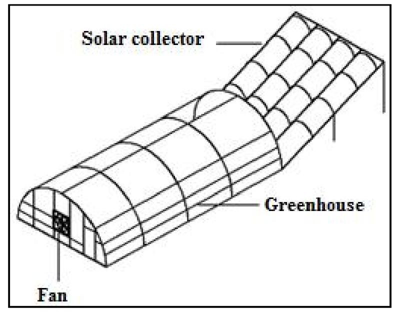

Fig. 1. Greenhouse type dryer

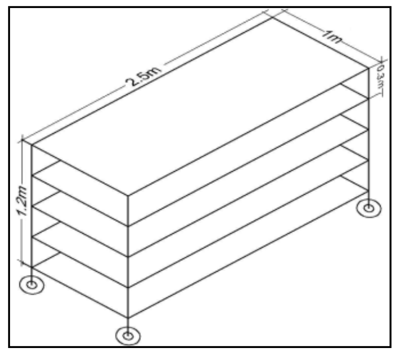

Fig. 2. Product drying racks

Temperature and relative humidity values in the outdoor and greenhouse dryers during the drying period were recorded with portable data measuring-recording systems (Sensitivity: 0.6°C temperature and 0.5% relative humidity, Software: Box Car Pro 3.7). The initial moisture content of each of the 20 grams products was determined by the etuv method (24 hours at 105°C) to determine the initial moisture before the drying process starts. In the weighing process, a digital scale (Sartorious BL 15005) which can measure ± 0.01 g sensitivity was used. The following equation is calculated to determine the percentage change in the percentage of red pepper samples in drying,

$$m_y = \frac{m_o - m_t}{m_o} \times 100 \quad (1)$$

In this equation;

- m_y= Percent change in mass in the progress of drying of red pepper (%)
- m_0= Pre drying mass of samples (g)
- m_t= The mass of samples at the weighing moments during the drying process (g)

Trials were performed by using three replicated and randomized plot designs. To determine the effects of drying environments on the drying of the products, the percentage change data were used as dependent variables. Variance analysis was performed with the help of SPSS 13.0 statistical program. Minolta Spectrometer Minolta CR-100 was used for colour measurements of fresh and dried products. To determine the colour changes in the products which were dried in the dryer with fresh products, colour measurements were performed in 20 times in fresh products, and 3 times in the dried products for each product analyses trials. Measurements were made in L * a * b * mode at the C position of the device. Product colour change was also observed and recorded during colour change measurements. The vertical L * axis, which changes from black to white, gives the brightness value and can take values ranging from 0 to 100 depending on the measured colour on the Lab-scale [13]. When the a * axis on the colour space has a positive value, the measured colour is red, and when it is negative, it becomes green. The metric tint (α; hue) is calculated from the following equation, depending on the a * and b * values:

$$\alpha = \arctan \frac{b*}{a*} \tag{2}$$

C* is a dimensionless value indicating metric chromium and can take values ranging from 0 to 60. Metric colour chroma is calculated from the equation given below based on the a * and b * values:

$$C* = \sqrt{a*^2 + b*^2} \tag{3}$$

In contrast to the common drying method, the red peppers to be dried were washed first and not the whole, then the stalk was pulled and divided into two, dried after the seed house was removed. In the production of spice red pepper in Southeastern Anatolia Region, the varieties of red pepper are more preferred by the spice industry producers because they are more appealing to the consumer taste. The varieties of thick red pepper, but not as a whole by the manufacturer, after pulling the stem, the seed slot, after being dried clean, easier and higher prices can be marketed. The thickness of the fruit flesh in Sena, which is registered in the Southeastern Anatolia Region, ranges from 1.4 kalın to 1.8 mm., on the other hand in Maraş 1, it changes between 1.2 and 1.4 mm [14]. No research on the effect of drying the thickness of the fruit flesh on spicy paprika was found. However, it is expected that the thick red pepper with thick fruit should dry later. To compare the red pepper dried in the greenhouse type dryer, the product of the same density is laid on the drying rack 50 cm above the ground directly under the sun. Drying time and colour measurements were performed in the experiments, temperature, proportional humidity, wind velocity and radiation values were recorded. Reductions in product mass during the drying process were measured every two to three hours due to the prolonged drying phase. The drying process was continued until the product mass in each rack decreased by about 1/5.

2.1.1 Yield calculations

2.1.1.1 Calculation of the efficiency of air solar collector

The air solar collector efficiency used before the dryer is defined as the ratio of the energy received by the air to the solar radiation coming to the collector [15,16,17,18,19]. The efficiency of the cool solar collector is calculated using the following equation:

$$\eta_c = \frac{Q_a}{Q_c} x100 \tag{4}$$

$$Q_c = A\, I_c \tag{5}$$

η_c : Efficiency of the cool solar collector (%),
I_c : Instantaneous solar radiation intensity from the solar collector (W/m^2),
A : Sun collector surface area (6 x 6 = 36 m^2),
Q_c : Total amount of instantaneous solar energy from the solar collector surface (W),
Q_a : Amount of useful heat energy (W).

Utilized heat is the heat energy that is gained from the collector. The mass flow of the working air is calculated by the following equation depending on the specific heat of the flow and the inlet and outlet temperatures of the fluid to the solar collector:

$$Q_a = m_a C_p \Delta T$$
$$Q_a = m_a C_p (T_0 - T_i) \tag{6}$$

m_a : Mass flow of air (kg/s),
C_p : Specific heat of the air (kJ/kg^{o}C),

ΔT : The difference between air collector inlet and outlet temperature (°C).

2.1.1.2 Drying room and calculation of drying efficiency of the system

This efficiency is defined as the ratio of the energy that is required to evaporate the product moisture to the energy that is supplied to the dryer. Mathematically, system drying efficiency, ɳd is calculated by the following equation [19,20].

$$\eta_d = \frac{M_w L}{Q_d} x100 \quad (7)$$

The amount of energy that is transferred to the product in the drying chamber is calculated by the following equation depending on the specific heat of the air and the inlet and outlet temperatures of the drying chamber:

$$Q_d = m_a C_p \Delta T$$
$$Q_d = m_a C_p (T_0 - T_i) \quad (8)$$

η_d : Dryer efficiency (%),
M_w: Water mass that evaporated from the product (kg),
L : Latent heat of evaporation of water (MJ/kg),
Q_d : The amount of energy transferred to the product in the drying chamber (W),
m_a : Mass flow of air (kg/s),
C_p : Specific heat of air (kJ/kg^{0}C),
ΔT : Inlet and outlet temperature change at ait drying room (°C).

It should be taken into account in the evaluation of efficiency in electricity consuming devices for evaluation of efficiency in forced circulation solar-powered dryers, fan and so on [19,20]. In this case, the drying efficiency of the system ɳd is calculated by the following equation:

$$\eta_d = \frac{M_w L}{Q_d + P_f} \times 100 \quad (9)$$

Differently from this;

P_f : The amount of energy consumed by the fan (kWh) is defined as

Hybrid type among solar energy, as well as a second heat source (biomass, LPG, electricity, etc., other fuels and resources) dryers using the system efficiency, is defined while other heaters should be taken into consideration. In this case, the drying efficiency of the system is calculated by the following equation:

$$\eta_d = \frac{M_w L}{Q_d + P_f + Q_{R2}} \times 100 \quad (10)$$

In this equation, terms as different;

Q_{R2} : Additional energy (kWh) from the second heat source.

System drying efficiency is a measure of the total efficiency of the drying system. However, the desiccant is not decisive by oneself in the evaluation of the study. Because of the efficiency of the product dried, air temperature, airflow format, wind speed, air solar collector and dryer design variables such as efficiency factors and desiccant design factors such as efficiency and these quantities directly or indirectly affect the system's thermal losses. System drying efficiency in natural convection dryers can reach % 20-30 values in dryers of forced transportation while it is 10-15% [19,20].

2.1.2 Determination of technical and economic performance factors of dryers

2.1.2.1 Determination of technical performance factors of dryers

In the technical evaluation of the dryer in the first and second periods, the following technical performance factors were considered. The heat energy that losses from the dryer to the external environment can be neglected as compared to the heat energy spent to increase the temperature of the product and the heat energy that used to vaporize the moisture in the product. The heat energy that is used to vaporize the moisture in the product is calculated using the equation given below [21].

$$Q_e = m_a(C_i T_i - C_o T_o)z \quad (11)$$

Q_e: Heat energy that spent evaporating product moisture (kJ),
m_a: Mass air flow rate (kg [air]/h),
C_i and C_o: Specific temperature of dryer inlet and outlet air (kJ/kg°C),
T_i and T_o: Desiccant inlet and outlet air temperature (°C),
z: Drying time (h).

The mass airflow rate that given to the dryer is calculated from the following equation:

$$m_a = 3600\frac{v}{\rho} \quad (12)$$

v : air flow rate (m^3/s);
ρ : Specific volume of moisture air (m^3/ kg).

The specific volume of humid air (ρ) and the specific temperature of the humid air entering and exiting the dryer (*Ci* and *Co*) were calculated by a computer program with MS-Excel software in Equation 11 and 12 [22].

The total energy delivered to the dryer was calculated using the equation given below [23].

$$Q_t = Q_h + fP_e z \quad (13)$$

Q_t : Total energy supplied to the dryer (kJ),
Q_h : Heat energy is given to the dryer (kJ),
P_e : Consumption of electrical energy in the dryer (kW),
f : Power factor of electric motor (f = 0.75).

Dryer efficiency is determined from the equation given below [24].

$$\eta = \frac{Q_e}{Q_t}100 \quad (14)$$

The consumption of desiccant specific heat energy is the heat energy spent by the dryer to remove the unit moisture in the product, calculated using the following equation [24].

$$Q_s = \frac{Q_h}{\Delta G} \quad (15)$$

Q_s: Desiccant specific heat energy consumption (kJ/kg_{water}),
ΔG: Evaporated mass of water (kg).

The consumption of desiccant specific electrical energy is the electrical energy that is consumed by the dryer to obtain unit dry material, calculated using the following equation [24].

$$P_s = \frac{fP_e z}{\Delta G} \quad (16)$$

P_s : The consumption of desiccant specific electrical energy (kJ/kg_{su}).

In the third term, the technical performance factors as given below are considered in the technical evaluation of the dryer. The heat energy used to evaporate moisture in the product is calculated using by Equation 11.

The mass airflow rate given to the dryer was determined by using Equation 12. The total heat energy delivered to the dryer was calculated by using equation 13 as given below:

$$Q_h = m_a(C_i T_i - C_{am} T_m)z \quad (17)$$

C_{am}: Specific temperature of the mixture air (kJ/kg°C),
T_m: Temperature of the mixing air (°C).

Dryer efficiency was calculated by using Equation 14. The specific heat energy consumption of the dryer was calculated by using Equation 16, and the specific electrical energy consumption by using Equation 15.

2.1.2.2 Determination of economic performance factors of dryers

First investment cost; $ 2,500 for the first and second periods and 5% of the initial investment costs are taken as annual maintenance and repair costs. The labour cost that required for the operation of each of the dryers is 2 workers / 24 h and the calculations are based on 35$ labour cost for 2 workers / 24 h. Electrical energy cost that is used as a heater in the third cycle dryer is adjusted as based upon TEDAŞ industrial type active energy prices as of August 2009 period. Accordingly, the cost of electrical energy is 0.173 $/ kWh [25].

Dried red pepper sale price is 6,6 $/kg. It was taken into consideration that in the red pepper that the products are collected three times per year and the average wet product yield in every form is 19 450 kg / ha and the dryer is used in continuous drying of red pepper for 3 months (90 days) per year. In the economic evaluation, the useful life of the high plastic tunnel type dryer used in the study was taken as 10 years, the scrap values as 0, and the minimum acceptable profit rate was taken as 10%. Depreciation expenses of dryers are determined from the equation given below with correct-line depreciation method [26].

$$D_t = \frac{C_{sp} \quad S_v}{n} \quad (18)$$

D_t: Desiccant depreciation expense in period t ($/yıl),
C_{sp}: Current value of drying system ($),

S_v: Scrap value ($),
n : Drying system useful life (year).

The net present value (*Np*) and unreduced repayment period (*Cn*) methods were used to determine the efficiency of the dryer investments. The net present values of the dryer investments can be defined as the difference between the current revenues and the defined income as the current time using the desired profit ratio. According to this method, if the current value of the cash flows is equal to or greater than the investment expenses, the project is profitable and should be accepted. The net present value of the investments is calculated from the equation given below [26].

$$N_p = \sum_{t=1}^{n} \frac{A_t}{(1+i)^t} \quad C_{sp} \tag{19}$$

N_p: Net present value of drying system ($),
A_t : Cash flow in period t ($),
i: Minimum acceptable profit rate (decimal).

The undiscounted or classic reimbursement period (C_n) of dryer investments is the time taken to earn the initial price of investment projects and is simply obtained by counting the periods until the cumulative cash flows are equal to the initial investment cost. When deciding between investment alternatives, the results of the net present value and repayment period methods should be evaluated together. The payback period is calculated using the equation given below [26].

$$C_n = \frac{C_{sp}}{A} \tag{20}$$

C_n: Classic payback period (year) ve A annual cash flow ($/year).

3. RESULTS AND DISCUSSION

Red pepper drying applications made in high plastic tunnel type dryer were performed in three periods. The first period is between 21-29.08.2008, the second period is 09-16.09.2008 and the third period is between 01-07.09.2009. Separate drying trials were performed for product densities of 2, 3, 4, and 5 kg / m^2 in each application period. In the first two periods only natural radiation was used, and in the third period, an additional electric heater was used in the high plastic tunnel. The best values were obtained in the experiments which were carried out in the first period with a product density of 5 kg / m^2. According to the results of the statistical analysis using mathematical models, the coefficient of determination (R^2) is the highest; determined by Two-Term model given by equality.

$$(M_t / M_o) = a\ exp(-k_1 t)+b exp(-k_2 t) \tag{21}$$

When the coefficients between the models, model coefficients and calculated values and experimental data are examined, the highest coefficient of determination is provided with Two-Term model and it is 0.9886-0.9977. This suggests that the model can be used in practice for estimation under the conditions of the experiment.

3.1 Collector and Drying Yield Calculations

The useful heat energy (Q_a) associated with the solar collector that used in front of the plastic tunnel, the efficiency of the solar collector (ηc) according to the total instantaneous solar energy (Q_c) values on the solar collector surface is calculated as 48.19% by using the equation 4. Condori et al. [27] reported that the efficiency of the collector used for heating the air that required for drying the product in the drying room is between 50-60%. The efficiency of the plastic tunnel drying system is defined as the ratio of the energy required for the evaporation of the product moisture to the energy supplied to the dryer. System drying efficiency, (ηd) No. 7 equation forced circulating solar energy dryers in the evaluation of efficiency fan and so on. The energy that is used in the devices has also been determined by using equation 9. Hybrid type, solar energy as well as a second heat source (biomass, LPG, electricity, other fuels and resources) by using the system efficiency in dryers, while the additional energy that is used in the evaluation of the system's drying efficiency (ηd) by using equation 8 is calculated as an average of 22.26%. Li and colleagues [28] reported that the drying efficiency value was 18.6%. System drying efficiency is a measure of the total efficiency of the drying system. However, the desiccant is not decisive factor in the evaluation of the study by oneself, because the product that is dried inefficiency, air temperature, air flow-form, wind speed, air solar collector, desiccant design etc. are efficient factors and these magnitudes are the parameters related directly or indirectly to the thermal losses of the system. In natural convection dryers, system drying efficiency can reach 10-15% while forced convection dryers can reach 20-30%. One such calculation was performed by Condori in a tunnel type dryer that used for drying of pepper and garlic. In this study, yield values of 8 days were reported at 25% levels [28].

3.2 Findings on Technical and Economic Performance of Dryers

3.2.1 Findings on technical performances of dryers

Table 1 presents the results of technical performance values of the drying system for red pepper dried in the plastic tunnel at different product density in the first period. The drying time varies between 13 and 23 hours by depending upon the drying conditions and the amount of dried material. The drying time changes between 13 and 23 hours depending on the drying conditions and the amount of dried material. The drying time remains the same despite the increase in the mass of the material which was dried in the drying trials in the loading quantities ranging from 112.5 to 150 kg. As it is known, in high plastic tunnel type shelving dryers, the first product on the upper shelves is on the drying process and then it is followed by lower shelves respectively. This trend happened similarly in the first-period trials. Drying process continued to allow the products in the lower shelves of the dryer to reach the same level of humidity as the products on the upper shelves after drying the upper shelves. In this case, although the products in the upper shelves were drier than the lower shelves, the drying process was terminated after reaching the humidity level of 10% (w.b.) in the lower shelves. Drying efficiency varies between 12.48% and 37.78% depending on the drying conditions and the amount of dried material.

The highest yield value was obtained from the experiment carried out in the amount of 187.5 kg loading, followed by the trials of loading load of 150, 112.5 and 75 kg respectively. Desiccant specific heat energy consumption and specific electrical energy consumption values decrease due to the increase in loading amount. The specific heat energy consumption values of the dryer change from 1911.48 to 6693.32 kJ / kg-water and the specific electrical energy consumption values obtain between 153 and 233.31 kJ / kg-water. The lowest specific heat and specific electrical energy consumption values were obtained in the loading amount of 187.5 kg. Buschbeck et al. [29] and Müller et al. [30] compared to 10000 kJ / kg-water and 8640 kJ / kg-water for medical mint, relatively lower specific heat energy consumption values were obtained.

When the values of drying performance are evaluated together with 187.5 kg material in the first period, it is observed that the values such as drying rate, drying time and dryer efficiency are the highest, specific heat energy and specific electricity energy consumption values are at the lowest values. Ancak 187.5 kg yükleme miktarında yapılan denemede kurutulan ürünlerin ulaştığı son nem değeri, 75 kg yükleme miktarında yapılan denemelerle karşılaştırıldığında yüksektir. However, the final moisture value of the products which are dried in the loading amount of 187.5 kg is higher compared to the trials that performed in the loading amount of 75 kg.

This situation is not a major problem in the storage of the dried product, but due to the lower moisture content of the 75 kg loading amount, the desiccant has caused relatively higher heat and electrical energy consumption values. In this case, it can be concluded that drying of red pepper in the first period and drying capacity between 75 and 187.5 kg according to the scale of drying and optimum drying can be provided by drying capacity. However, when the physical structure of the dryer and the dried material is taken into account, it is not possible to dry the product in an amount of more than 187.5 kg. Table 2 indicates the technical performance values for drying in different loading quantities for the second period. The drying time varies between 14 and 23 hours by depending on the drying conditions and the amount of dried material. Drying time at the loading amount between 75 and 187.5 kg increased the drying time according to the increase in the mass of the dried material. Drying efficiency changes between 15.39% and 34.16% by depending on the drying conditions and amount of dried material. The highest yield value was obtained in the experiment that performed with a loading quantity of 187.5 kg, followed by trials in the loading volume of 150.75 and 112.5 kg, respectively. The consumption of desiccant specific heat energy and specific electrical energy values decreases with an increase in loading quantity. The specific heat energy consumption values of the dryer change between 2137.1 and 4015.92 kJ / kg-water, while the specific electrical energy consumption values change between 151.91 and 244.99 kJ / kg-water. The lowest specific heat and electrical energy consumption values were obtained at the loading amount of 187.5 kg. When the values of dryer technical performance are evaluated together, it is seen that the values such as drying rate, drying time, and dryer efficiency are the highest, specific heat and electrical energy consumption values are at the lowest values in case the system is loaded with 187.5 kg material in the second period. However, the final moisture value of the products that dried in the test performed at the loading amount of 187.5 kg is high compared to the trials carried out in the loading amount of 75 kg. While this doesn't constitute a major problem in the storage of the dried product, the desiccant has caused relatively high thermal and electrical energy consumption values are lower as the last moisture value reaches at the 5 kg loading amount. In this case, it can be concluded that in the second period, the optimum amount of plastic tunnel dryer capacity can be obtained by drying at loading quantities between 75 and 187.5 kg.

Table 3 represents the findings of the technical performance values of the system in the third cycle drying experiments. Drying time increased according to the increase in the mass of the dried material in the loading amounts ranging from 75 to 112.5 kg during the drying trials. The drying time, on the other hand, changes between 24 and 28 hours by depending upon the drying conditions and the amount of dried material. The reason for this increase is due to the forced circulation of solar-powered dryers, fan and so on in addition to Hybrid type with the energy that used in the devices is the evaluation of the additional energy (electricity) in the dryers that use a second heat source besides the solar energy. Drying efficiency changes between 20.42% and 23.70% by depending upon drying conditions and the amount of dried material. The highest yield value was obtained from the experiment performed at a load of 112.5 kg, followed by an experiment at the loading amount of 75 kg, respectively. Desiccant specific heat and electrical energy consumption values decrease due to an increase in loading amount. The specific heat energy consumption values of the dryer change between 5171.36 and 6802.7 kJ / kg-water, while the specific electrical energy consumption values vary between 308.98 and 387.33 kJ / kg-water. The lowest specific heat and electrical energy consumption values were obtained in the loading amount of 112.5 kg.

Table 1. Technical performance values achieved in the first period

Drying parameters	Product density (kg/m^2)			
	2	3	4	5
Initial moisture(% w.b.)	82	83.10	82.70	82.80
Final moisture (% w.b.)	9.83	10.04	9.92	10.05
Loading capacity(kg)	75	112.50	150	187.50
Vaporised water ΔG(kg)	60.09	89.92	119.91	150.17
Drying time(h)	13-14	20-21	20-21	22-23
Relative humidity of inlet air(%)	24	31.40	19.10	23.80
Avg. Drying speed (kg-wt/h)	4.29	4.28	5.71	6.52
Dryer efficiency(%)	12.48	18.73	20.07	37.78
Specific heat ener. consumption (kJ/kg-wt)	6693.32	3879.65	3727.69	1911.48
Specific elect.ener. consumption (kJ/kg-wt)	232.71	233.31	174.94	153

Table 2. Technical performance values achieved in the second period

Drying parameters	Product density (kg/m^2)			
	2	3	4	5
Initial humidity(%w.b.)	82.20	82.40	81.90	81.70
Last humidity(%w.b.)	9.98	10.10	10.02	10.30
Loading capacity(kg)	75	112.5	150	187.50
Evaporated water ΔG(kg)	61.16	91	119.18	151.25
Drying time (h*)*	14-15	21-22	20-21	22-23
Relative humidity of inlet air(%)	19.30	39.20	21.60	21.80
Avg. drying rate(kg-wt/h)	4.11	4.14	5.67	6.58
Dryer efficiency(%)	17.33	15.39	25.16	34.16
Specific heat energy consumption (kJ/kg-wt)	4015.92	4863.57	2792.40	2137.10
Specific electrical energy consumption (kJ/kg-wt)	244.99	241.51	176.03	151.91

Table 3. Technical performance values achieved in the third period

Drying parameters	Product density (kg/m^2)	
	2	3
Initial humidity(% w.b.)	82.10	82.70
Last humidity (% w.b.)	9.98	10.04
Loading capacity(kg)	75	112.50
Evaporated water ΔG(kg)	59.32	90.53
Drying time(h)	24	28
Relative humidity of inlet air(%)	21	23.10
Avg. drying rate(kg-wt/h)	2.47	3.12
Dryer efficiency(%)	20.42	23.70
Specific heat energy consumption(kJ/kg-wt)	6802.70	5171.36
Specific electr. energy consumption (kJ/kg-wt)	387.33	308.98

When the values of the dryer technical performance are evaluated together, it is observed that in the third period, if the system is loaded with 112.5 kg wet material, the values such as drying speed, drying time, and dryer efficiency are obtained highest value, on the contrary, fuel consumption, specific heat and electrical energy consumption values are calculated as the lowest values. However, the final moisture value of the products which are dried in the experiment in the amount of 112.5 kg loading is high compared to the experiments that performed in the loading amount of 75 kg. In this case, it can be concluded that drying of red pepper in the third-period dryer with drying scale in the amount of 75 to 112.5 kg depending on the scale of the enterprise and the drying requirement can provide optimum benefit from the dryer capacity.

3.2.2 Findings related to economic performance of dryers

Table 4 shows the economic performance values of the first period. In the first period, the dryer has a drying capacity of 0.671 tonnes and 1.680 tonnes of red pepper (as a wet crop) per year by depending on the amount of red pepper loaded into the dryer. In this case, 2.705 tons to 6.76 tons of water per year from the red pepper with 80% humidity by depending on the loading density. Because there are 3 decimals in the red pepper and the yield is 19.45 ton/ha, the drying capacity of the area varies between 0.17 and 0.44 ha/year by depending on the drying density of the dryer. However, the net present value of the investment increases to 187.5 kg in terms of loading performance depending on the loading density. The most economical drying capacity will be calculated as a 0.41 years payback period and 187.5 kg loading amount with 29057.26 $ net present value by Considering the net present value factor and repayment period together. In the first period, 187.5 kg loading quantity in terms of both technical and economic performance factors was determined to be the most suitable capacity for drying red pepper with this system.

Table 5 shows the system's economic performance values for the second period. In the second period, the dryer has a capacity of drying between 0.601 tonnes and 1.618 tonnes of red pepper per year by depending on the red pepper mass loaded in the dryer. In this case, 2.774 tonnes and 6.82 tonnes of water are removed per year from the red pepper with an average humidity of 80% depending on the loading density. Because there are 3 times at harvesting in the red pepper and the yield is 19.45 ton/ha, the drying capacity varies between 0.17 - 0.43 ha/year depending on the drier loading density. In the second period, where a shorter payback period is calculated between 0.41 and 0.97 years depending on the loading density, the first investment costs are met in the first period as well as in the first period. However, depending on the loading density, the net present value of the investment increases to 187.5 kg loading quantity. When the net present value factor and payback period are evaluated together, the most economical drying capacity will be 0.41 years payback period and 28772.27 $ net present value with 187.5 kg loading amount. In the second period, the best values in terms of both technical and economic performance factors are obtained at 187.5 kg loading density.

Table 6 shows the economic performance values obtained in the third period. In the third period, red pepper drying capacity was reached between 0.706 tonnes and 0.989 tonnes per year by depending on the red pepper mass loaded in the dryer. In this case, the average performance of the product with 80% humidity is 2.669 tonnes

Table 4. Economic performance values achieved in the first period

Economic parameter	Product density (kg/m^2)			
	2	3	4	5
Capacity(kg dry product/year)	670.55	1016.21	1353.81	1679.56
Evaporated water(kg /year)	2704.55	4046.29	5396.19	6757.91
Field capacity(ha/year)	0.17	0.26	0.35	0.43
Total annual expenditur($/year)	4328.60	4440.53	5452.47	6014.40
Total annual income($/year)	4425.59	6707.00	8935.12	11085.10
Repayment time(year)	>1	0.92	0.60	0.41
Net current value(P/A, 10.10).$	---	11826.48	19299.38	29057.26

Table 5. Economic performance values achieved in the third period

Economic parameter	Product density (kg/m^2)			
	2	3	4	5
Capacity(kg dry product/year)	600.81	967.50	1387.10	1617.57
Evaporated water,(kg /year)	74.19	4095	5362.90	6819.93
Field capacity(ha/year)	0.17	0.26	0.35	0.43
Total annual expenditur($/year)	183.47	4222.85	5162.22	5651.6
Total annual income($/year)	965.39	6385.52	9154.88	10675.96
Repayment time(year)	>1	0.97	0.53	0.41
Net current value (P/A,10.10).$	----	11188.70	22433.15	28772.27

Table 6. Economic performance values achieved in the second period

Economic parameter	Product density (kg/m^2)	
	2	3
Capacity(kg dry product/year)	705.969	988.75
Evaporated water,(kg /year)	2669.03	4073.75
Field capacity(ha/year)	0.17	0.26
Total annual expenditur($/year)	4918.92	4992.05
Total annual income($/year)	4659.39	6525.77
Repayment time(year)	>1	1.36
Net current value (P/A,10.10).$	----	7324.05

and 4.074 tonnes of water by depending on the loading density. Because there are 3 times at harvesting in the red pepper and the yield is 19.45 ton/ha, the drying capacity of the area varies between 0.17 - 0.26 ha/year depending on the drier loading density.

In the third period in which the redemption period is calculated as 1.36 years depending on the loading density, it does not meet the first investment cost and cannot make a profit in a season in contrast to the first and second periods. However, the net present value of the investment increases to 112.5 kg loading depending on the loading density. When the net present value factor and payback period are evaluated together, it is observed that the most economical drying capacity is the payback period of 1.36 years and the net present value of 7324.05 $ is 112.5 kg at loading performance. The maximum drying capacity of 112.5 kg in which the third cycle dryer has the best values in terms of both technical and economic performance factors has been determined as the most suitable capacity for drying red pepper with this dryer.

4. CONCLUSION AND RECOMMENDATIONS

In this study, it was determined that the product dried in the greenhouse was dried in a few hours shorter than the product dried in the external environment according to the total drying time. This process is very fast in the first phase of drying when the water is removed physically. In practice, it is observed that after the first 5-6 hours of drying, the mass loss is reduced and the drying is slowed down. The most important advantage in favour of the greenhouse dryer is that the product is dried in a clean environment without exposure to any contamination. Nowadays, increasingly competitive conditions make it possible to achieve superiority not only with the price of the finished product but also with the elements of food safety and quality. For example, one of the quality parameters, which were dried in the greenhouse in terms of colour, was found to have a brighter red colour than the samples dried outdoors. Therefore, it is essential to dry the product in a clean environment with a reasonable investment and operating cost, with a minimum loss of quality and quantity. On the other hand, temperatures above 60°C in the greenhouse will contribute to the disinfection of the storage pests in the product. In the greenhouse type dryer, it is necessary to take the technical measures to increase the aggregate efficiency and increase the ambient temperature provided in the greenhouse. It was determined that the temperatures in the greenhouse during the experiments were between 55-60°C for 3-4 hours. As the length of the greenhouse module increases, the radiation from both the collector and the greenhouse will be used more. Moreover, the hot air will go a long way in the greenhouse. Undoubtedly, to prevent heat losses in the greenhouse, providing good insulation and recirculation of the greenhouse air by reintroducing the greenhouse air are the first measures that will enable the utilization of the heat gained in the collector for a longer period. On the other hand, if the conditions in which the producer sell the product dried in a greenhouse at a different price, the option of heating with the burner may be brought to the agenda to ensure continuous drying in the night periods. However, the heating during the night will increase the unit drying costs in terms of both burner investment and operating costs. In this study, it was determined that the optimum loading capacity can be increased to 187.5 kg in terms of technical and economic performance criteria taken into consideration in the study of red pepper drying carried out in 3 different periods. Considering that this plastic tunnel has a floor area of 48 m^2, it is calculated that a mass of 187.5 / 48 = 3.9 kg / m^2 can be dried at a loading scale considering the maximum loading capacity. If the prototype used in the trial is evaluated effectively in the floor area and height of the plastic tunnel and furthermore, it will not be suspected that this figure will increase in a commercially length plastic tunnel. However, it can be obtained that the fresh material can be dried in the unit area of the plastic tunnel only after drying trials in a commercial plastic tunnel. On the other hand, according to the results obtained in the first period with the optimum loading capacity calculated, it has been determined that the plastic tunnel dryer can meet the first investment, operation and fixed expenses in a season and it is a profitable investment. This result is a convincing justification for the fact that plastic tunnel dryers can be offered to producers. In addition, the positive contribution of the drying in a plastic tunnel, in a closed environment, in terms of food safety and quality, is suitable for other undergrowth and drying activities in addition to the drying season, and in the case of production where the production is carried out, Advantages should also be noted as reduction. In this way, the economic profitability of the system can be increased by making maximum use of the plastic tunnel.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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