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Original Article

Analysis of Energy Consumption Rate in Drying Process of Corn Using Dryer Reservoir in Different Temperature and Height of Layer

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A R T I C L E I N F O

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A B S T R A C T

Objective: Drying is one of the most important post-harvesting processes in agriculture. Drying method and also drying time have an important effect on the amount of energy required. In this study analysis of energy consumption for drying corn in dryer reservoir with flow of warm air and the effect of the temperature and height of product layer on the amount of energy consumption per unit mass were investigated. **Methods:** Drying experiments at five different temperatures (70, 80, 90, 100 and 110˚C) and the height of product in the reservoir in four different levels (20, 40, 60 and 80 cm) and at a constant speed of air flow (1 meter per second) were performed in three replications. Results were analyzed using SPSS software. **Results:** The results showed that the product at temperature of 100˚C with layer height of 60 cm had the minimum amount of energy consumption per unit mass while at temperature of 70˚C with layer height of 20 cm the maximum amount of energy consumption per unit mass occurred.

1. INTRODUCTION

From yields per hectare point of view, corn is the most high-yielding cereal grown in the world and placed after wheat and rice. It is one of the most important cereals in many countries with total production exceeding 844 million tonnes. Corn is used as the main ingredient in livestock feed and also processed into a multitude of food and industrial products including starch, sweeteners, corn oil, beverage and industrial alcohol, and fuel ethanol. Corn harvested at high moisture content requires rapid drying for safe storage to prevent respiration, germination, mold damage and insect infestation (Gursoy et al, 2013). One of the important post-harvesting processes in agriculture is drying products. Since the duration of drying has an important effect on economic yields and the amount of required energy, therefore, checking the effect of drying conditions on the energy consumption is very important. In order to optimize energy consumption, it is needed to attention to management of the agricultural products drying including drying process, precise control of other factors affecting the drying time and etc (Sharifi et al., 2010). Drying is considered as an energy-consuming act with great economic importance because it is consuming a lot of energy in industrial drying (Sahin & Dincer, 2002). Corzo et al (2008) were analyzed energy and exergy of the thin layer drying of coroba slices at three different air temperatures (71, 82 and 93˚C) and velocities (0.82–1.00 and 1.18 m/s). The effects of inlet air temperature and velocity and drying time on both energy and exergy were studied. Both energy utilization

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and energy utilization ratio increased with increasing drying time while exergy efficiency decreased. The values of energy utilization and energy utilization ratio were found to be in the range of 0.009–0.65 kJ/s and 0.00007–0.008, respectively. Akpinar et al (2006) examined the amount of energy and exergy of potato drying process. Samples used in this study are sufficiently dried in the ranges between 60 and 80˚C and 20% and 10% of relative humidity at 1 and 1.5 ms¯1 of drying air velocity during 10-12s. In these experiments, the energy losses were calculated 796/1-0 KJ safely. The first and second laws of thermodynamics were used to calculate the useful and wasted energy during the drying process. Sharifi et al (2010) in a research were investigated energy consumption rate in drying process of a thin layer bergamot in laboratory. The effects of air temperature, velocity of dryer and thickness of bergamot thin sheets on required energy were gained. In these experiments, bergamot sheets, with five different temperatures (40, 50, 60, 70 and 80°C) and air velocities (0.5, 1 and 2 m) and three thicknesses (2, 4 and 6 mm) were dried. The results showed that the highest and lowest energy consumption of dryer related to the thickness of 2 mm and a temperature of 40 ° C with 3458 energy of watts - hour and the thickness of 6 mm and a temperature of 70 °C with 14306 energy of watts – hour, rsepectively. In this study analysis of energy consumption for drying corn in dryer reservoir with flow of warm air and the effect of the temperature and height of product layer on the amount of energy consumption per unit mass were investigated.

2. MATERIALS AND METHODS

2.1. Laboratory equipment

Laboratory dryer with warm air flow and fixed bed was used for doing experiments. The dryer is made of a blower for airflow, two heating units to heat the incoming air (each unit heaters are 4 elements), thermocouples, and an indicator for measuring and controlling temperature, The linear airflow for uniform velocity of heated air of dryer reservoir in cross-section, a digital scale for reading the weight loss during testing, cylindrical reservoir for product placement, flow meters to measure the electricity consumption. To achieve steady-state conditions, all experiments ware started 30 minutes after turning on the system, and then the seeds were placed in the reservoir. Air flow passing through corn seeds and warmed them and absorbed their moisture. Thus, increasing temperature will accelerate the moisture out of the product.

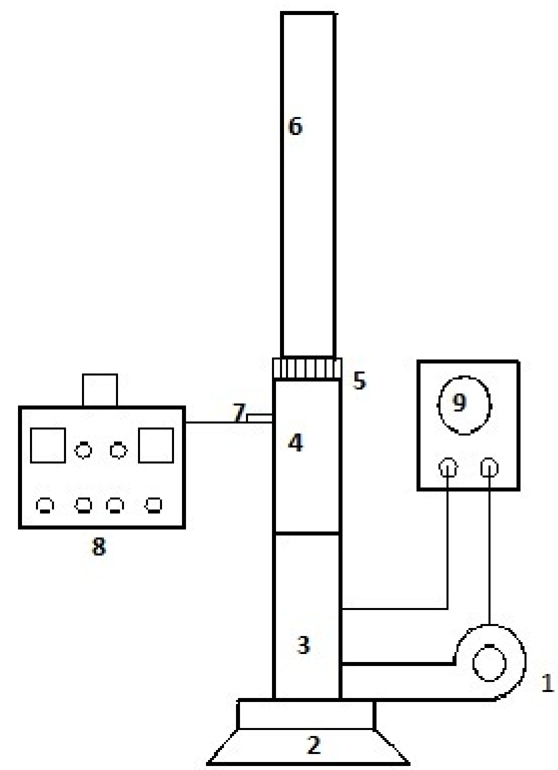

Fig 1. Schematic of the Laboratory dryer (1. blower, 2. digital scale, 3, 4. Heating units, 5. Linear airflow, 6. Cylindrical, 7. Thermocouples, 8. Indicator, 9. Flow meters)

2.2. Sample preparation method

Corn kernels used for testing were placed into plastic bags that do not have any exchange of moisture with the environment. Then, to prevent moisture loss and corruption of seeds were maintained in cold storage at 6 °C and 90-60 percent relative humidity. Before each experiment, the samples were manually winnowed. The chaff and straw, stones, dirt and foreign materials have been removed. Then samples were placed inside the lab room to reach equilibrium with the ambient temperature. Drying experiments were conducted at temperatures (70, 80, 90, 100 and 110˚c) and the height of the seeds in reservoir (20, 40, 60 and 80 cm) in three replications.

2.3. Test method

Corn poured into the reservoir according to each of the heights as mentioned and initial weight was recorded. During the test, the required time for drying the product (using a timer with an second accuracy) and product weight with digital scale (in the interval five grams of weight) were measured and recorded. Drying process would continue until reaching approximately weight 14% on dry basis. The initial moisture content of the samples was obtained in an oven at 130 °C for 24 h (ASAE. 1982).

2.4. Calculation of energy consumption

Flow meters were used in these experiments for calculating the energy consumption of blower and heaters, thus the number of meter read at the beginning and end of each experiment. The effect of different temperatures and heights on energy consumption was discussed using SPSS software.

3. RESULTS AND DISCUSSION

3.1. Analysis of energy graphs

According to the results are given in Figure 2, with increasing inlet air temperature from 70 to 100 °C, energy consumption is reduced and it's reason can be that as the temperature increased, testing time and energy consumption is reduced. But by increasing inlet air temperature to more than 1000c, the amount of energy consumption continues to increase. Therefore we can say increasing temperature to reduce the energy consumption has a certain limit. In this figure, at temperature of 1000c the minimum amount of energy consumption and at temperature of 700c the maximum amount of energy consumption occurred.

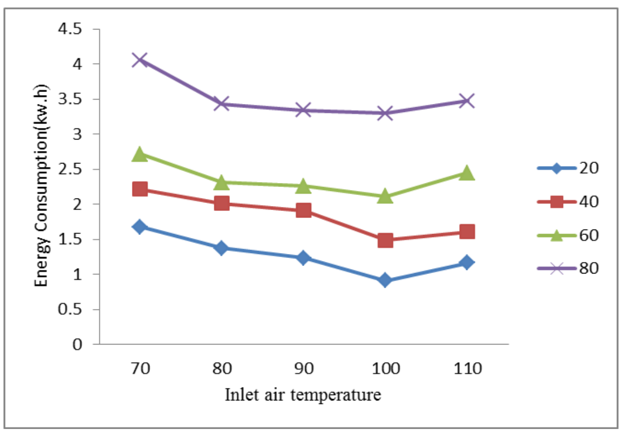

Fig 2. Energy consumption by increasing the temperature and height

As seen in Figure 3 by increasing the height of product layer energy consumption increases. Therefore, the amount of energy per unit mass is given in Figure 3 and it is observed that the amount of energy per unit mass of 60 and 80 cm height is lower than 20 cm height. Because the amount of heat energy that it is still usability is being wasted in the height of 20 cm. This wasted amount on the upper heights is used as optimal. In Figure 3, the amount of energy consumption per unit mass is given. As it is observed by increasing the height of product layer from 20 cm to 60 cm, the amount of energy consumption per unit mass reduces but by increasing the height of product layer to 80 cm the energy consumption increases again. It can be said, in height of 20 cm and 40 cm some usable thermal energy wasted but by increasing the height of product layer to 60 cm, this amount is used optimally. Therefore in this dryer it is better to choose the height of 60 cm. In height of 80 cm the amount of energy consumption is more than it was in 60cm but in this height less energy consumption is observed compared to height of 20 cm and 40 cm.

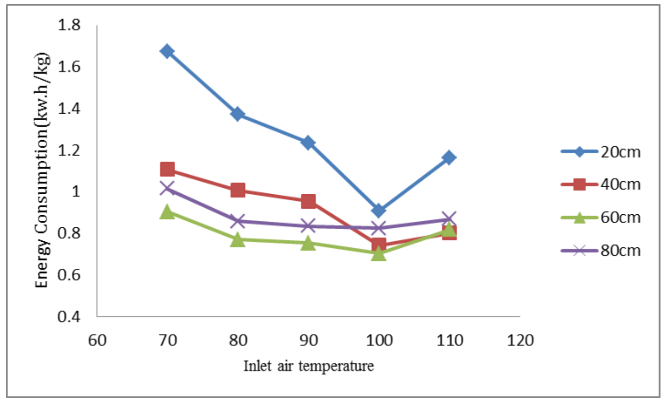

Fig 3. Energy consumption per unit mass

3.2. Correlation coefficients

To evaluate the effect of each independent variables (Inlet air temperature and the height of the kernels in reservoir) on dependent variable (The amount of energy consumption per unit mass) calculation results of Pearson and Spearman correlation coefficients are listed in in Table 1 and Table 2.

According to Table 1, The Pearson correlation test (r = -0.444) between temperature and the amount of energy per unit mass is not significant at the 1% error level but there is a significant negative correlation at 5% error level. The value of the Pearson correlation test (r=-0.615) between the height of the product in the reservoir and the amount of energy per unit mass is negative and significant at the 1% error level, i.e. the amount of energy per unit mass decreased with increasing height.

According to Table 2, It is observed that the Spearman correlation test (r=-0.457) between temperature and the amount of energy per unit mass isn't significant at the 1% error level, but at the 5% error level, there was a significant negative relationship.

Also, The value of the Spearman correlation test (r=-0.528) between the height of the product in the reservoir and the amount of energy per unit mass of product isn't significant at the 1% error level, but at the 5% error level, there was a significant negative relationship.

Considering Tables 1 and 2 above, we can say increasing temperature and height reduces the amount of energy per unit mass.

3.3. Multivariate regression to estimate equation

Correlation of independent and dependent variables in a multivariate linear regression shown in Table 3 were analyzed using SPSS software. Height and temperature variables are explaining 76% of the variation in energy use. Considering the significance of the final multivariable regression model, energy consumption can be estimated using the following equation.

If we show the temperature with T and the height with H:

Y = 1.956 - 0.007 T – 0.007 H

According to the all mentioned points, it can be said that in order to optimize the energy consumption in dryers we should use the factors that has less amount of energy. The product at temperature of 100˚C with layer height of 60 cm had the minimum amount of energy consumption per unit mass while at temperature of 70˚Cand layer height of 20 cm the maximum amount of energy consumption per unit mass occurred. But in general increasing temperature reduces energy consumption and increasing height reduces the energy consumption per unit mass.

Table 1:

Pearson correlations between independent and dependent variables

Dependent variables / independent variable	The amount of energy consumption per unit mass		
	correlation coefficient	Significance level	Error level
temperature	**-0.444**	**0.05**	**0.05**
height	**-0.615**	**0.004**	**0.01**

Table 2:

Spearman correlation between the independent and dependent variables

Dependent variable / independent variable	The amount of energy consumption per unit mass		
	Correlation coefficient	Significance level	Error level
Temperature	**-0.457**	**0.043**	**0.05**
Height	**-0.528**	**0.017**	**0.05**

Table 3:

Results of multivariate regression analysis (independent variables effect on the dependent variable)

Variables	B	Beta	t	sig
Constant	**1.956**		**7.675**	**0.000**
Temperature	**-0.007**	**-0.444**	**-2.809**	**0.012**
Height	**-0.007**	**-0.615**	**-3.889**	**0.001**

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