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Comparison of Energy and Cost Analysis of Two Different Industrial Corn Drying Plants Using Solid Fuel

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ABSTRACT: In this study, the energy and cost analyzes of two different corn drying plants using solid fuel in the heating of drying air are performed. In the evaluated drying processes, corn which has high humidity, dried to a value below 15% relative humidity which is the storage humidity. In the drying process, thermodynamic properties such as temperature, relative humidity and air velocity of the node points determined in the systems were measured. The continuous operating temperatures of the facilities specified for analyzes were taken into account. In the analyzes, measurements were made for the drying air inlet temperatures of drying plants which was drying temperature of 70°C and 112°C. Based on the results obtained at the determined nodes, the influences on the inlet temperature of the drying air, the thermal value of the fuel, the fuel consumption, the energy efficiency and the unit drying cost have been evaluated. As a result, it has been found that the increase in inlet air temperature reduces boiler efficiency and energy efficiency, increases unit drying cost and fuel consumption. It has been found that high thermal value fuel usage has an important role in decreasing drying time as it allows working at high temperatures

KEYWORDS: Drying, Corn Drying, Grain Drying, Energy and Cost Analysis Comparison

I.INTRODUCTION

Due to the fact that our country is a gas importing country and because of the increases in gas prices, various amount of drying facilities in our region are being switched to a more economical coal drying systems. Transitions in these systems provide economic gain, but the dehumidification capacity of the system is lowered as the air flow in the hot air boilers is lower than that of the gas-operated systems, and as a result of that the drying time is prolonged.

In this study, the thermodynamic properties of two coal-fired systems were measured under normal operating conditions. Energy efficiency and unit drying costs of the obtained data are calculated. In the first to be tested plant low-quality coal with a lower heat value of 4000 is used, while the second to be tested plant using high quality imported coal with a lower heat value of 7600. The use of quality coal and product with high moisture content allows operation at a drying air temperature as high as 112°C in second plant, while the use of low quality coal and the lower drying temperature of the drying air at 70°C are preferred in the first plant.

II. LITERATURE SURVEY

In a study made by Unal [1], using a thermo economic method, thermo economic analysis was performed on the unit equipments belonging to the second unit of a thermic central located in Turkey. Individual node points in the system were determined and the flow chart of the system was established. The thermodynamic properties of twenty-seven knots at which the thermal power plant is located are determined and the energy and exergy values of each knot are calculated according to these determined characteristics. Energy and exergy balances were established for each equipment with the calculated results and average exergy costs were determined and energy and exergy which were lost and destroyed were determined and exergoeconomic analysis was carried out with the aim of determining the amount of exergy which was lost.

In a previous study reported by Yilmaz [2], single layer corn drying experiments were carried out in three stages. In the first phase; single layer corn samples were continuously dried at 40°C, 45°C, 50°C, 55°C, 60°C, 65°C and 70°C temperature at air velocity of 2m/s. In the second phase, single layer corn samples were rested for 30 minutes after 30 minutes of drying. This process continued until the desired moisture content was reduced. In the third step, the corn samples were taken for 60 minutes of resting period after 30 minutes of drying. It has been determined that in order to reach the surface of the noodle in the maize, it is necessary to stop the drying process at the intermediate place during the drying and to continue the drying process after waiting for the noodle to come to the surface for saving energy in the drying process. When examination was performed regarding the drying time, it has been found that the drying time is changed in a relatively direct manner from the drying mode.

Kuzgunkaya and Hepbasli [3] performed a process of drying the bay leaf with hot air produced by an earth-borne heat pump in a tumble dryer cabinet. The drying temperatures of the drying air were increased by 40°C, 45°C and 50°C for a certain period of time. It has been determined that the efficiency of the exergy, the losses and the development potential are increased by increasing the inlet temperature to the drying cabinet.

Kuzgunkaya and Hepbasli [4] identified the energy efficiency of the system in a different study after the nodes were identified in the same drying system. As a result of this study, it was determined that the heat pump unit used for drying was 21.1% for exergy efficiency, 20.5% for soil heat pump and 15.5% for the entire drying system.

In a study done by Trace [5] drying parameters were determined when corn was dried by hot air flow. For this purpose, 700 kg capacity hot air drying system was designed and manufactured. The experiments were carried out in this system. The experiments were carried out at a fixed output rate of 1m/s, at a temperature of 45°C, 55°C, 65°C, 75°C and atmospheric temperatures with from 16.4% humidity to corn safe storage humidity value of 10%. The parameters such as drying speed, germination rate, germination power, energy consumption, drying properties and cost have been determined in experiments carried out at five different temperature values using mixer and mixer-free tests.

Akpınar et al. [6] analyzed energy and exergy analysis of the process of drying sliced red peppers and strawberry samples in a dry type dryer. As a result of the analysis, the change of the exergence with time was observed in the drying chamber, the expulsion efficiencies of the drying chamber and the losses occurring in the drying chamber were also calculated.

In a study by Erbay and Hepbasli [7], they examined the effect of condenser, evaporator and compressor improvement on exergy and energy efficiency, with a loss of exergy loss in a drying system in which drying air is produced by an earth source heat pump. As a result of the analysis, it was determined that the energy and exergy efficiency reached 77.05% and 93.5% respectively.

Significant amounts of energy are being spent in industrial drying plants. Industrial corn drying facilities are widely used in the Southeast Anatolia region in recent years. The fact that there is no such a work done in energy and cost analysis in the industrial drying plant in the literature, distinguishes this work from other studies and brings it to the fore. With this study, it is ensured that the same system, which works with different operating conditions, is required to determine the most favourable conditions in terms of energy efficiency and unit drying cost.

III. METHODOLOGY

Coal is used as a fuel in horizontal type corn drying plants where this work is done. As shown in Figure 1, the system is divided into four groups as heating group, cooling group, drying process and transport group. In the heating group consisting of hot air boilers, the heated air is sent to the drying process, where the product transferred to the flow divisions by the spiral system comes into contact with the drying air and releases the moisture into the air. Fresh air is blown into the product by the fan in the cooling group, making the product temperature ideal for storage. Moist air is ejected from the perforated side sheets, while the dried product is transported to the dry product pool by the spool system.

The machine, which is generally divided into two parts, can be heated in two parts as well as in the upper part while cooling can be done in the lower part. The air heated by the fan heater group is then sent to the drying volume. The air coming into the drying chamber takes moisture of the corn flowing out of the vented chrome side sheets and throws it out. The dried product is collected in a controlled manner by collecting on the rotating spiral under the rolls. By measuring the humidity, the speed of the system is adjusted according to the desired values.

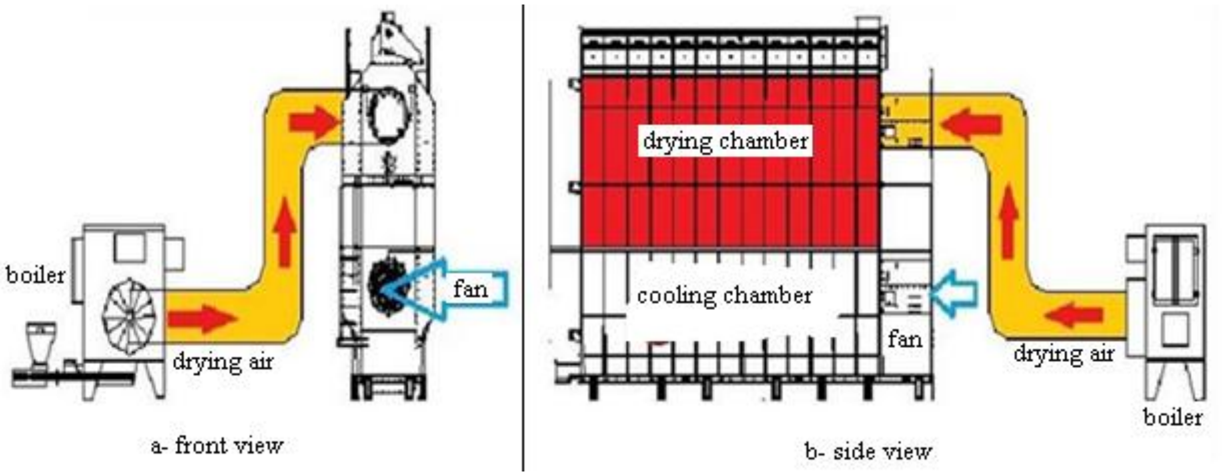

Figure 1. Horizontal Type Solid Fuel Corn Drying Machine

As indicated in Figure 2, there are 8 knot points determined in the system. Thermodynamic properties such as temperature, relative humidity and air flow rate were determined at node points. The thermodynamic properties of the determined node points are found individually and in accordance with the flow diagram.

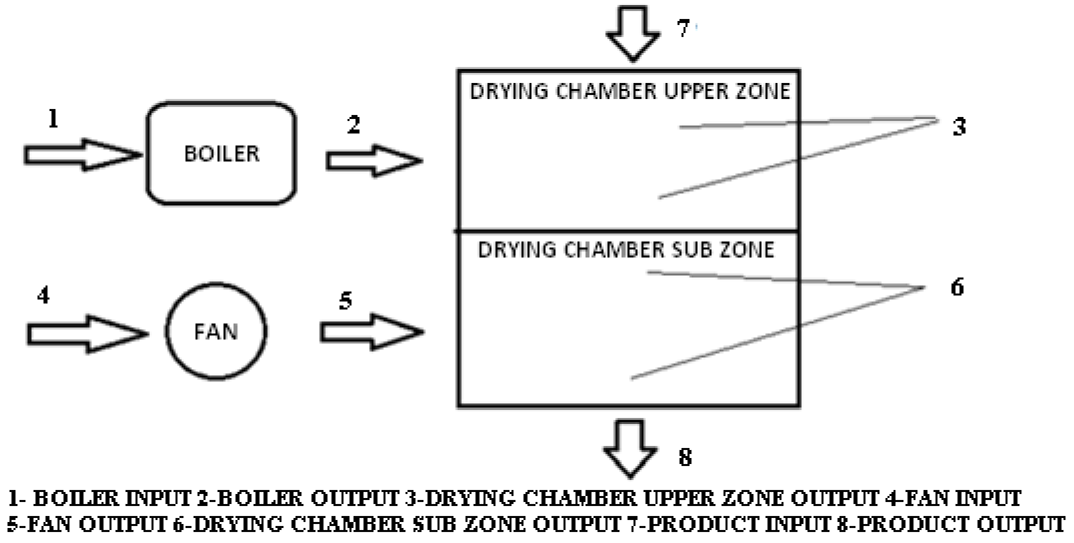

Figure 2. System Node Points

In the analyzes made in the maize drying plant, continuous flow acceptance was prepared and it was tried to be determined simply by the equations related to the energy exchange of the system, the humidity of the drying air and enthalpy. By using the inlet and outlet temperatures of the heater, the useful energy gained from the heater is calculated. In the analysis, the total energy losses at the inlet and outlet of the drying chamber were calculated. Energy efficiency is determined by using the calculated energy values for the input and output conditions of the node points determined on the system. The thermodynamic equations and acceptances used in the calculations are given in Table 1.

Table 1. Used equations and acceptances

NUMBER	DESCRIPTION	EQUATION
1	Conservation of massfordryair	$\sum \dot{m}_i = \sum \dot{m}_o$
2	Conservation of massforhumidity	$\sum \left(\dot{m}_{ai}.w_i + \dot{m}_{water} \right) = \sum \dot{m}_{ai}.w_o$
3	Conservation of energy	$\dot{Q} - \dot{W} = \sum \dot{m}_o \left(h_o + \frac{v_o^2}{2} \right) - \sum \dot{m}_i \left(h_i + \frac{v_i^2}{2} \right)$
4	Beneficialenergysavedfromtheheater	$\dot{Q}_{utility} = \dot{m}_{da} c_{p_{da}} \left(T_{hi} - T_{ho} \right)$
5	Thermalenergyuseddduringdehumidification	$\dot{Q}_{dc} = \dot{m}_{da} \left(h_{dai@T} - h_{dao@T} \right)$
6	Energyefficiency of heather	$\eta_{heater} = \frac{\dot{Q}_{utility}}{\dot{Q}_{fuel}}$
7	Energyefficiency of system	$\eta_{system} = \frac{\dot{Q}_{dc}}{\dot{Q}_{fuel}}$
8	Dryingcost of a unit	$UDC = \frac{\text{amount of dried product}(kg)}{\text{fuel consumption}(tl)}$
a : air, c: chamber, d : drying, h : heating, i : input, o: output, UDC : Unit Drying Cost, tl : Turkish Lira		

The thermodynamic properties required for the analysis were determined by measuring devices placed at the nodal points. The measurement data are shown in Table 2. Some measurement values that continue at near values are considered fixed.

Table 2. Experimental Data Obtained from the First Corn Drying Plant

MEASURED VALUE	EXPERIMENTAL NUMBER			
	1 (70 °C)	2 (70°C)	3 (70°C)	4 (70°C)
AMBIENT TEMPERATURE (°C)	19.4	20.4	21.8	17.6
RELATIVE HUMIDITY (%)	55	55	23	53
CORN INPUT HUMIDITY (%)	23.3	24.4	22.2	21.5
CORN OUTPUT HUMIDITY (%)	14.8	15.1	14.3	13.8
CORN INPUT TEMPERATURE (°C)	20.4	20.4	20.4	22.2
CORN OUTPUT TEMPERATURE (°C)	46.4	47.1	45.2	46.9
AIR FLOW (m^3/h)	36000	36000	36000	36000
DRY WAVE INPUT TEMPERATURE (°C)	70	70	70	70
FUEL CONSUMPTION (kg coal)	200	200	200	250
AMOUNT OF DRYING PRODUCT (kg)	28100	27350	27450	26850
EXPERIMENT TIME (min)	70	68	65	78
CONSUMED ELECTRIC (kW)	126	122	117	140

Table 3. Experimental Data Obtained from the Second Corn Drying Plant

MEASURED VALUE	EXPERIMENTAL NUMBER			
	1 (112°C)	2 (112°C)	3 (112°C)	4 (112°C)
AMBIENT TEMPERATURE (°C)	21.5	20	17.5	23.4
RELATIVE HUMIDITY (%)	53	48	51	65
CORN INPUT HUMIDITY (%)	28.5	26.8	27.8	25.3
CORN OUTPUT HUMIDITY (%)	14.1	14.5	13.6	15.2
CORN INPUT TEMPERATURE (°C)	22.2	20.5	21.3	23.5
CORN OUTPUT TEMPERATURE (°C)	55.7	53.8	54.8	55.3
AIR FLOW (m^3/h)	36000	36000	36000	36000
DRY WAVE INPUT TEMPERATURE (°C)	112	112	112	112
FUEL CONSUMPTION (kg coal)	450	450	450	450
AMOUNT OF DRYING PRODUCT (kg)	20150	22000	21000	21350
EXPERIMENT TIME (min)	156	148	160	164
CONSUMED ELECTRIC (kW)	260	246	266	273

IV. EXPERIMENTAL RESULTS

As a result of the experimental analyzes made, the corn drying facility heater and the obtained data of the system are examined, and the energy efficiency of the heater is shown in Fig. 3 with the beneficial output temperature.

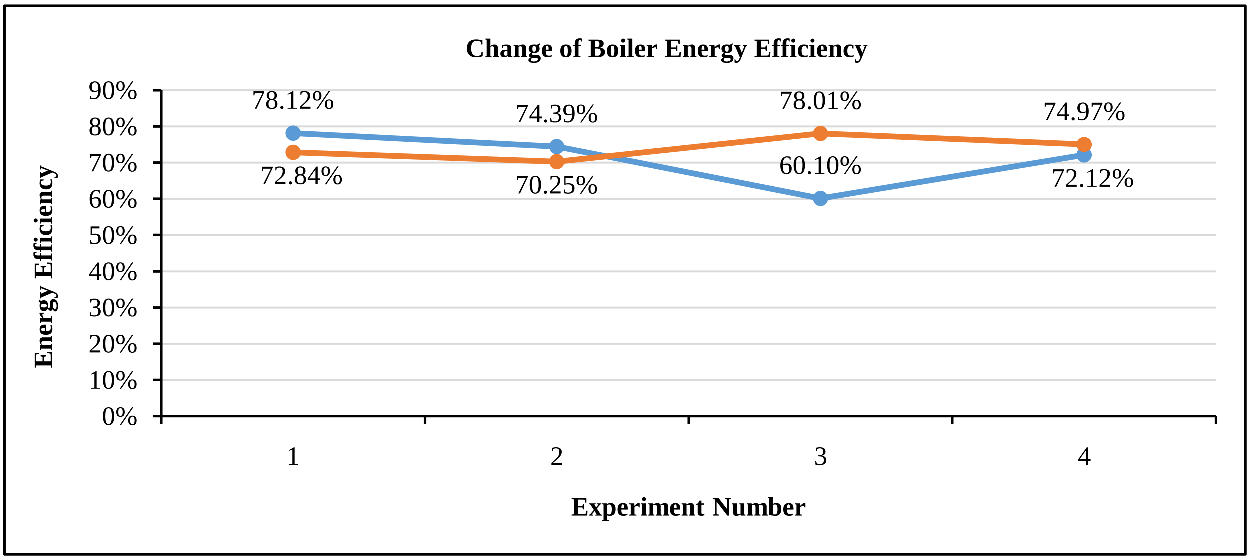

Figure 3. Output Temperature Change of Energy Efficiency of Heater

As a result of the inspection as shown in Figure 3, it was concluded that the heater efficiencies in the two systems were close to each other.

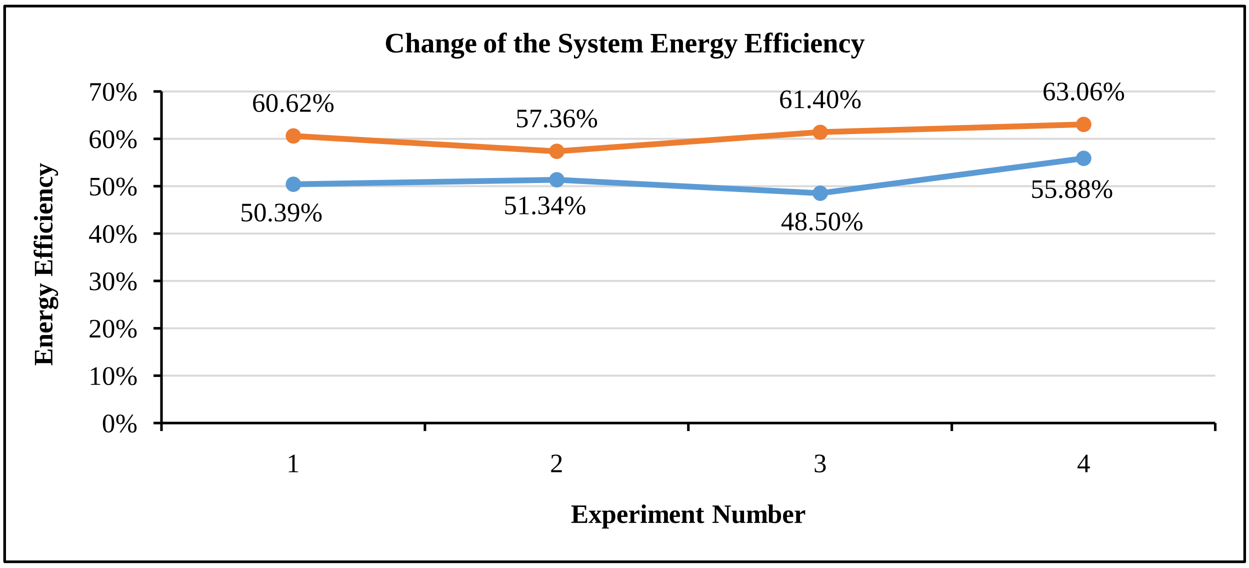

Figure 4. Change in Energy Efficiency of the System with Drying Air Temperature

As shown in Figure 4, the energy efficiency of the first system running at low temperature is found very deficient, while the energy efficiency of the system should tend to increase inproportion to the decrease in the inlet temperature of the drying air in the drying chamber. The main reasons for this result are the very low consumption of fuel and the lower value of the cornworking at a temperature below 80°C which is the ideal drying temperature.

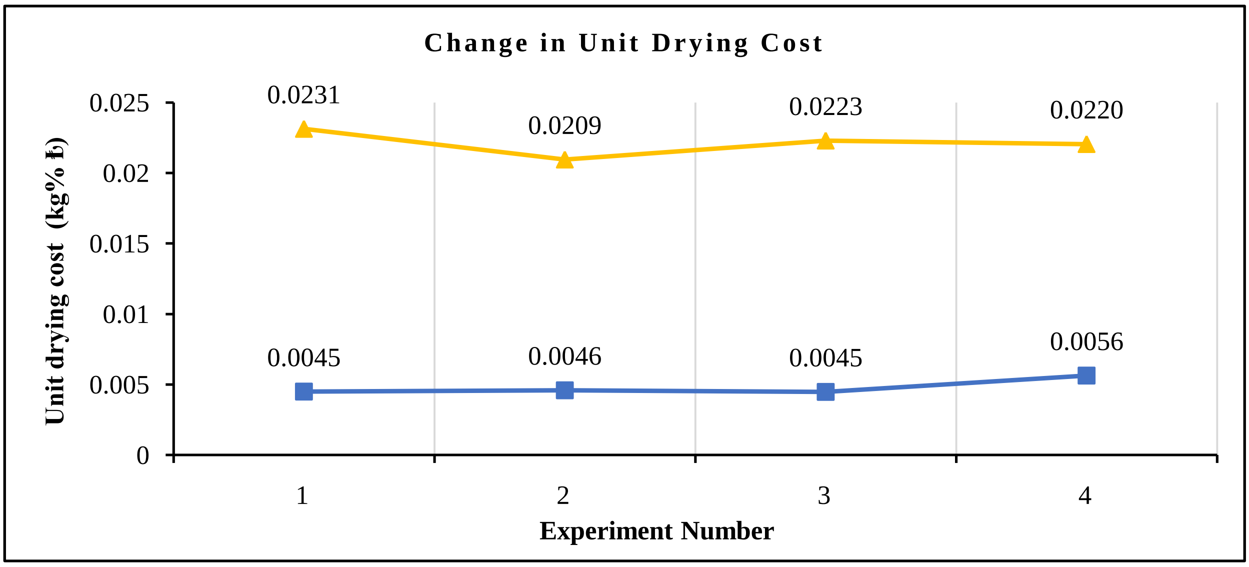

Figure 5. Change of Exergy Efficiency with Air Inlet Temperature

As a result of the investigation, it is clearly seen in Figure 5 that the drying air reduces the unit drying cost by decreasing the inlet temperature to the drying chamber.

V.CONCLUSION

As a result of this study, it has been shown that although the energy efficiency is low using low-temperature and low-temperature coal, the unit drying cost is also low, which makes the working condition highly preferable. The first plant does not provide high humid corn drying and high temperature operation and the second plant is not preferred in terms of cost and energy efficiency. However, the second plant can be used to save time on corn drying process.

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AUTHOR'S BIOGRAPHY

Ast. Prof. Dr. Fatih Ünal graduated from mechanical engineering in Dumlupınar University with a high degree of honor in 2006. Fatih Ünal graduated his master and Ph. D. in Yıldız Technical University in 2009 and 2014, respectively. He has been working as an academician at Mardin Artuklu University since 2009. He is currently the Head of the Department of Machinery and Metal Technologies Program. Fatih Ünal studies in the fields of energy, exergy, renewable energy and heat transfer.