STUDIES REGARDING THE DESIGN OF GRAIN DRYERS WITH RENEWABLE ENERGY SOURCES

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Abstract: *With increasing concern for environmental degradation, it is desirable to decrease energy consumption in all sectors. Thus, the paper presents the cereals' drying process as an important energy consumer. The main input and output thermal components involved in the heat balance are investigated. Likewise, the possibilities to use the gasification process as energy source are further analyzed. Using the MathCAD and Labview software, the behaviour of the drying system was simulated considering both temperature variation and humidity content of the environment. In conclusion, the paper shows the great potential for using gasification in cereals drying process from the following points of view: quality of dried products, energetic efficiency and global costs.*

Key words: *renewable energy sources, grain drying.*

1. Biomass, an Universal and Renewable Energy Source

Biomass as a universal and renewable energy carrier is going through a renewal regarding technology development and reputation. As well as the positive environmental effects of biomass-based energy supply there are several social and economical aspects, as the harvesting, treatment and transport of biomass are labour intensive. With 1.75 new long-term jobs per generated gigawatt-hour of bioenergy comes a significant net job creation - an important criterion for the sustainable development of rural areas both in the EU and in most of the other countries.

In general, regional areas profit directly from the positive economic effects of using bio-energy. In contrast to an added value of 20% in the fossil-fuel-based energy sector, bio-energy projects provide an added value of 60% to the region.

On the land areas of our planet grow about 200 billion tonnes of biomass with an energy content of approximately 30,000 EJ (1 EJ = 1 exajoule = 1.0E+18 J). This is equivalent to the energy content of the entire stock of fossil energy carriers on earth. Each year, a growth of about 15 billion tonnes of biomass adds an energy potential of 2250 EJ to this amount through photosynthesis.

Unfortunately this vast potential cannot be used directly for energy purposes, as it is spread over the entire landmass of our planet (Figure 1). Only part of this potential is available for the use of biomass as an energy carrier; it is called the technical potential, and has been estimated to be of the order of 150 EJ.

2. Strategies for Implementing the Biomass as Primary Energy Sources

Renewable energy sources are considered a priority. For example, in Slovenia, about 70

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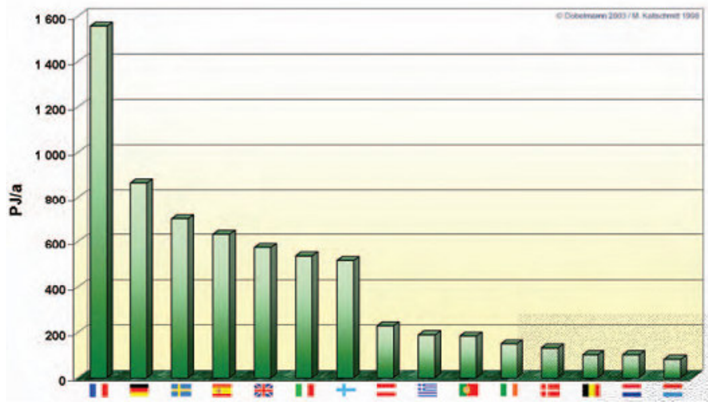

Fig. 1. *Technical potential of biomass in Europe* [5]

percent of the country's total primary energy needs are imported, and so renewable energies are considered an important national strategic reserve as well as providing environmental and social benefits.

In 1994, the heat and hot water supply for Slovenia's industry, residential and public buildings accounted for approximately 30 percent of total energy consumption, and produced about 28 percent of the country's total greenhouse gas emissions of 14.34 million tons of CO_2.

Existing coal and wood heating systems have an estimated 50 percent average efficiency Installation of new, correctly sized and more efficient equipment could raise this to 80 percent. In buildings, which use old, oversized oil- or gas-fired boilers, the installation of new boilers could increase efficiency from current 75 percent to around 90 percent.

As well as increasing the efficiency of existing biomass boilers and small individual fireplaces the Slovenian National Energy Plan (NEP) aims to increase the share of wood biomass (currently 4.4 percent) within the primary energy balance by 50 percent. An analysis conducted by the Slovenian Forestry Institute under this project's preparatory phase supports this goal by estimating the total unused potential of industrial wood waste, brushwood, and other unrealized resources to be over 600,000 tons of wood biomass annually.

One specific application consists in grain drying. In order to obtain proper long term storage of cereals, these products need to be dried to low moisture contents. It is an energy intensive operation, consuming about 0.38…0.63 GJ/t of grain. Drying has been reported to account for about 12…20% of the energy consumption in the agricultural sector. Though not all cereal grain is artificially dried, it has been estimated that about 34% of the world's cereal crop is grown in nations where artificial drying is needed for some of the crops [4].

The majority of artificial drying operations are based on hot air drying, where air is heated by the combustion of fossil fuels prior to being forced through the product. This type of drying requires high energy inputs, due to the inefficiencies of such dryers [4].

Often, the exhaust air is simply released to the surrounding ambient air. Some systems allow for the recycling of exhaust heat, which can greatly increase the overall energy efficiency of the dryer. In recent years, many researchers have attempted to analyze the possibility to use the biomass as energy source for grain dryers, the same source point being an important advantage in applying this technique.

In Figure 2 the frame energies involved in the typical grain dryer work flow are shown, where: G - air flow rate, m^3/min; H_1, H_2 - humidity of ambient and heated air, kg/kg; H_3 - humidity of exhaust air, kg/kg; RH_1, RH_2 and RH_3 - relative humidity of ambient, heated and exhaust air; t_1, t_2 and t_3 - dry bulb temperatures of ambient, heated, and exhaust air respectively, ºC; W_d - total weight of bone dry grain in the dryer, kg; X_1, X_2 - initial and final moisture contents of grain, kg/kg; G_1, G_2, t_1, t_2 - initial and final grain temperatures, ^{0}C; V_1 = initial humid volume, m^3/kg.

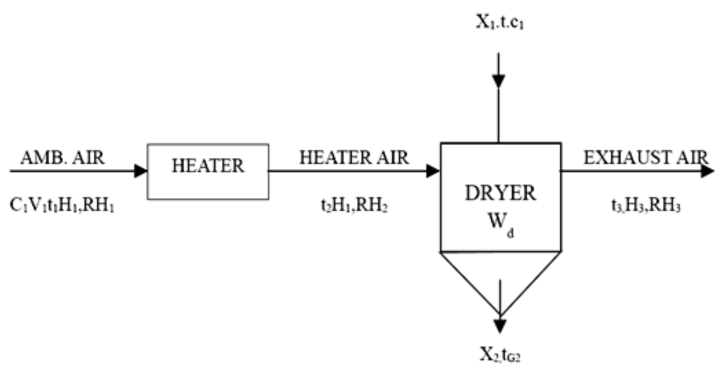

Fig. 2. *Mass and heat balance in grain dryer*

3. Comparison between Different Energy Sources Utilisable In Drying Techniques

Generally the direct firing system is used for gaseous and liquid fuels and the indirect heating system using heat exchangers is employed for solid fuels. But direct flue gas from the husk fired furnace can also be efficiently used for the grain drying. The drying cost can be further reduced by introducing solar - cum - husk fired grain drying system.

Using these values, starting from balance equation, simulation using MathLAB & MathCAD software was developed. Figure 3 shows the energetic balance of the grain dryer in two distinct situations:

- using methane gas as energy power source;
- using gasification technique to heat the dryer.

In Figure 3a, the fuel consumption varies from the medium value 28 Nm^3/h to 12 Nm^3/h with the increase of seed temperature; as compared to the situation, shown in Figure 3c, in which the fuel consumption varies from the medium value 34 Nm^3/h to 16 Nm^3/h with the same seed temperature range. As a conclusion, a 21% value increase is observed.

In Figure 3b, the fuel consumption varies from the medium value 14 Nm^3/h to 15.8 Nm^3/h with the increase of seed humidity; as compared to the fact, shown in Figure 3d that the fuel consumption varies from the medium value 18 Nm^3/h to 20 Nm^3/h with the same seed humidity range. In conclusion, a 17% value increase is observed [1]. From the thermal point of view, these corrections have to be taken into consideration in the process of designing and adjustments of the automation system.

For drying purposes, each type of gasifier will operate satisfactorily with respect to stability, gas quality, efficiency and pressure losses only within certain ranges of the fuel properties, out of which the most important are: energy content, moisture content, volatile matter, ash content and ash chemical composition, reactivity, size and size distribution, bulk density, charring properties [2], [3].

Table 1 shows some parameters that have to be taken into consideration in order to choose a good drying energy source [4].

Different source of energy suitable for agrifood products drying Table 1

Nr. crt.	Fuel	Density, [Kg/m^3]	Heating value, [kJ/kg]
Agricultural Crop residues			
1	Bagasse, dry	-	18 600
2	Corn stalks dry	-	16 600
3	Cotton batting	-	16 550
4	Cottonseed hulls	-	20 000
5	Newspaper	-	18 330
6	Pecan shells	-	20 680
7	Straw	-	13 950
8	Wheat (Straw)	-	17 445
Alcohol - gas			
9	Ethyl (C_2H_5OH)	1.956	27750
10	Methyl (CH_3OH)	1.363	21115
Alcohol - liquid (pure)			
11	Ethyl (C_2H_5OH)	815.3	26240
12	Methyl (CH_3OH)	796.1	19580
Coal			
13	Anthracite	1.12...1.35	29772
14	Bituminous	1.12…1.35	31401
15	Semi-bituminous	1.12…1.35	33960
16	Manufactured briquettes	1.12...1.35	30355
17	Gasoline	736.9	43960
18	Kerosene	817.2	43403
Gas (C_nH_{2n+2})			
19	Natural methane (CH_4)	0.680	50055
20	Ethane (C_2H_6)	1.287	47488
21	Manufactured	0.769	24610
22	Propane (C_3H_8)	1.924	46390
23	Butane (C_4H_{10})	2.532	45775
24	Wood	-	20934

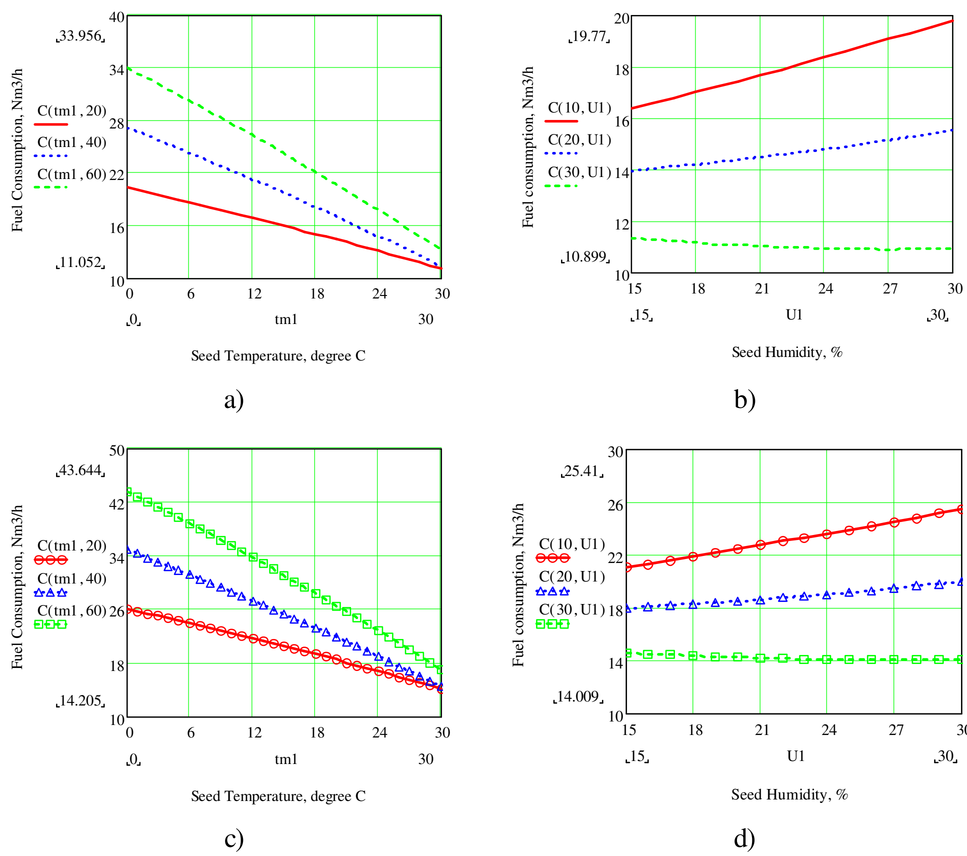

Fig. 3. *Consumption of fuel depending on the seed temperature and humidity*

4. Conclusion

The process of drying biological materials is very important in agro-food industry for producing high quality and long term stable products.

However, there is a downside to the process, as it is a high energy consuming process. This has two aspects, the first is the cost of energy, and the second is the environmental degradation that is associated with some types of energy production. In response to these concerns, there has been much work on new drying techniques to improve energy and drying efficiencies.

This paper proposes a new analysis, with the hope that these techniques, along with future research, will produce dryers and drying processes that are more economical and less harmful to the environment. The results obtained after the preliminary studies show that gasification can provide a good source of energy suitable for using even in the case of automated dryers.

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