Aspects into the use of renewable energy sources in cereals drying process

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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 behavior 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: - grain drying process, gasification, renewable energy sources

1 Introduction
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 (Raghavan, 2003).

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.

2 Energetic balance of drying process
Under these circumstances, the most important specific parameters of the drying process are hot air (combustion gas) circulation velocity, temperature of the drying agent and its relative humidity. Generally, high values of circulation velocity and temperature of the drying agent, as well as its low humidity improve the process, by increasing drying speed.

Optimization of these parameters is an important and complex problem, with direct effects on the efficiency of the dryer and the specific consumption of fuel. Difficulties occur due to variations of product or atmospheric air parameters.

Starting from the thermal equation of the grain dryer, (fig. 1), there results:

\[ \Sigma Q_i = \Sigma Q_o; \]
\[ \Sigma Q_i = Q_{cc} + Q_{sc} + Q_{SL} + Q_{sm}; \]  

(1)
\[ \Sigma Q_{ej} = Q_{sm2} + Q_{v} + Q_{ga} + Q_{prc} \]

where: \( Q_{di}, Q_{ej}, Q_{cc}, Q_{sc}, Q_{SL}, Q_{sm1}, Q_{sm2}, Q_{v}, Q_{ga}, Q_{prc} \) are the input, output, chemical heat of fuel, sensitive heat of fuel sensitive heat of air, sensitive heat of input material, sensitive heat of output material, used heat for water vaporization from the product, sensitive heat of combustion gases, lost heat by radiation and convection. By expressing these terms we obtain:

\[ Q_{cc} = C H_{ic}; \]
\[ Q_{sc} = C i_c; \]
\[ Q_{SL} = C \lambda V_{LMIN} i_L; \]
\[ Q_{sm1} = G_1 c_{m1} t_{m1}; \]
\[ Q_{sm2} = G_2 c_{m2} t_{m2}; \]
\[ Q_v = G_1 \frac{U_1 - U_2}{100} (i_{a2} - i_{a1}); \]
\[ Q_{ga} = V_{ga} i_{ga}; \]
\[ Q_{prc} = \Sigma Q_{ii} - \Sigma Q_{ej} = \eta \Sigma Q_{ii}, \]

where: \( C \) is the fuel flow; \( H_{ic} \) - caloric content of the fuel; \( i_c, i_L, i_{a1}, i_{a2}, i_{ga} \) - the enthalpies of the fuel, combustion air, input water and output water, combustion gases; \( \lambda \) - coefficient of air excess at the fuel combustion; \( V_{LMIN} \) - the minimum air volume used to fuel combustion; \( V_{ga} \) - combustion gases flow; \( c_{m1}, c_{m2}, t_{m1}, t_{m2}, U_1, U_2 \) - the specific heat, the temperatures, moisture of input and output materials. Therefore, the heat balance becomes:

\[ C H_{ic} + C i_c + C \lambda V_{LMIN} i_L + G_1 c_{m1} t_{m1} = G_2 c_{m2} t_{m2} + G_1 \frac{U_1 - U_2}{100} (i_{a2} - i_{a1}) + V_{ga} i_{ga} + \eta(C H_{ic} + C i_c + C \lambda V_{LMIN} i_L + Q_{sm1} + G_1 c_{m1} t_{m1}) \]

with solution:

\[ C = \frac{H_{ic} + i_c + \lambda \cdot V_{LMIN} \cdot i_L - \eta \cdot H_{ic} - \eta \cdot i_c - \eta \cdot \lambda \cdot V_{LMIN} \cdot i_L}{-\left( \frac{G_1 \cdot c_{m1} \cdot t_{m1} - G_2 \cdot c_{m2} \cdot t_{m2} - \frac{1}{100} G_1 \cdot U_1 \cdot i_{a2} + \frac{1}{100} G_1 \cdot U_1 \cdot i_{a1} \right) + \left( \frac{1}{100} G_1 \cdot U_2 \cdot i_{a2} - \frac{1}{100} G_1 \cdot U_2 \cdot i_{a1} - V_{ga} \cdot i_{ga} - \eta \cdot G_1 \cdot c_{m1} \cdot t_{m1} \right)} + \eta \cdot c_{m1} \cdot t_{m1} \]
An important parameter that influences the quality of dried cereal concerning both their adequate humidity diminishment and their future germination capacity, is the maximum temperature reached by the products in the drying room.

The reference material defines the maximum values of this parameter, which depends on the specific conditions under which the drying process is achieved. This is the reason why this quantity has to be permanently checked out, because it depends on the values of all the other quantities that are included in the thermal balance equation.

In order to emphasize the phenomenon from the quantitative point of view, a simulation of a drying process by means of the MATLAB/SIMULINK application was performed. This simulation can help us to determine the influence of the environmental daily temperature variation upon the maximum temperature of cereal plants during the drying process.

Therefore, drying equipment with permanent operation was chosen, where the drying conditions were automatically controlled by a system that maintained the temperature inside the drying room between two certain limits, taking into account of the outside influences.

![Diagram](image1)

**3 Energetic balance analysis**

Figure 2 shows the energetic balance of the grain dryer into two distinct situations:
- using methan gas as energy power source;
- using gasification technique to heat the dryer.

In figure 2.a, the fuel consumption varies from the medium value 28 Nm3/h to 12 Nm3/h with the increase of seed temperature; as compared to this, in figure 2.c, the fuel consumption varies from the medium value 34 Nm3/h to 16 Nm3/h with the same
seed temperature range. As conclusion, it is observed a 21% increasing value.

In figure 2.b, the fuel consumption varies from the medium value 14 Nm3/h to 15.8 Nm3/h with the increase of seed humidity; as compared to this, in figure 2.d, the fuel consumption varies from the medium value 18 Nm3/h to 20 Nm3/h with the same seed humidity range. In conclusion, it is observed a 17% increasing value. [2]

From point of thermal point of view, these corrections have to be taken into consideration in the process of designing and adjustments of automation system.

For drying purpose, 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. [1, 3].

Table 1, 2, 3 shows some parameters that has to be taken into consideration in order to choose a good drying source energy. [4]

### Tabel 1

**Average lower heating values for different fuels**

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Moisture (%)</th>
<th>Lower heating (kJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>wood</td>
<td>20 – 25</td>
<td>13000 – 15000</td>
</tr>
<tr>
<td>charcoal</td>
<td>2 – 7</td>
<td>29 – 30000</td>
</tr>
<tr>
<td>peat</td>
<td>35 – 50</td>
<td>12 – 14000</td>
</tr>
</tbody>
</table>

### Tabel 2

**Slagging of agricultural residues in a small laboratory down draught gasifier**

<table>
<thead>
<tr>
<th>Slagging fuels</th>
<th>Ash content Percent (%)</th>
<th>Degree of slagging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley straw mix</td>
<td>10.3</td>
<td>severe</td>
</tr>
<tr>
<td>Bean straw</td>
<td>10.2</td>
<td>severe</td>
</tr>
<tr>
<td>Corn stalks</td>
<td>6.4</td>
<td>moderate</td>
</tr>
<tr>
<td>Cotton gin trash</td>
<td>17.6</td>
<td>severe</td>
</tr>
<tr>
<td>Cubed cotton stalks</td>
<td>17.2</td>
<td>severe</td>
</tr>
<tr>
<td>RDF pellets</td>
<td>10.4</td>
<td>severe</td>
</tr>
<tr>
<td>Pelleted rice hulls</td>
<td>14.9</td>
<td>severe</td>
</tr>
</tbody>
</table>

### Tabel 3

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Moisture (%)</th>
<th>Lower heating (kJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safflower straw</td>
<td>6.0</td>
<td>minor</td>
</tr>
<tr>
<td>Wheat straw and corn stalks</td>
<td>7.4</td>
<td>severe</td>
</tr>
</tbody>
</table>

## 4 Conclusion

The process of drying biological materials is very important in agri-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 propose a new analyze, with hope that these techniques, along with future research, will produce dryers and drying process that are more economical and less harmful to the environment.

### References:


