Energy utilization of high-water content biomass in albanian rural areas

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Abstract: *The use of renewable sources for energy purposes is very important from the global environmental perspective. Biomass is part of this group of fuels. This article focuses on the characteristics of wet biomass, a typical fuel source in the Albanian rural areas and not only. Thus, the most significant factor of biomass combustion is its moisture content in natural conditions. This property significantly influences the burning quality of biomass. Drying of this fuel using conventional methods or energy intensity processes aims to decrease the moisture content in biomass and meantime increase of its calorific value. The techniques of drying wet biomass vary significantly. Energy utilization of wet biomass is the main goal of this paper, considering it an important fuel source especially during winter season in Albanian rural areas. The variation of heating value to moisture content and other significant parameters have been investigated.*

Keywords*:* MOISTURE, BIOMASS, ENERGY, HEATING VALUE.

1. Introduction

Naturally, biomass is one of the oldest resources that man has used to meet his needs [1]. Likewise, the technology of converting this fuel into useful energy is one of the most well-known and studied, but improvements and increased efficiency bring new challenges in this field as well [2l. Albania is situated in the Mediterranean with relatively small arable land [3]. Thus, the biomass resources of the country are limited. It is known that the main sources of biomass are forest waste, agricultural waste derived from processes, animal waste, urban waste, as well as energy crops [4]. The studies on the use and exploitation of biomass in general and fuel wood in particular in Albania were limited. In the cases where they have been carried out, they were partial, without taking into account the demographic developments, ownership changes, economic and political changes that our country experienced during the recent years [5]. In Table 1 is presented the biomass potential in the country. Firewood (biomass) represents about 52% of the renewable share in the Albanian energy consumption, where the other 48 % is electricity. It is widely known that the Albanian electricity production is largely based on hydropower [6]. The use of firewood is mostly dominant in rural areas of the country. In recent years the institutions have initiated actions in controlling the unlimited cuts of forests [7]. Although the situation has changed there is still poor progress in full control of the country's forest by legal authorities. Thus, except firewood other biomass resources have been used for heating purposes or processes requiring heat. Herbs, agriculture crops, olive mill waste, medicinal herbs etc., have been seen as a useful energy source. These typical biomass sources are commonly found in natural condition, and their energy utilization requires pre-processing such as drying, which results in cost increase for the end consumer. Therefore, the investigation of wet biomass parameters, such as moisture content, calorific values, ash content is seen as highly important in this article.

Table 1. *Biomass energy potential in Albania [8]*

Biomass	Theoretical potential (ktoe)	Share in national energy balance (%)	Technical potential (heat ktoe)	Technical potential (electricity ktoe)
Forest	263.6	1.07	234.4	70.3
Agriculture	1521.1	6.17	979.8	293.9
Urban Waste	1576.4	6.39	1276	382.8
Waste from trees	168.1	0.68	142.9	42.9
Livestock waste	585.25	2.37	521.6	156.5
Energy crops	62.3	0.25	57.1	17.13
Total	4176	16.9 %	3212	936.6

2. Energy utilization of wet biomass

Moisture content has a significant influence in the energy utilization of biomass [9]. Thus, in normal conditions the moisture content can vary from 15% found in dry straw up to 80% in wood or other products such as agricultural waste or various residues [10]. High water content will negatively affect in the calorific value. The dependency of moisture content and calorific value is given according to [11] by the relation (1) where the increase of water content causes the decrease of calorific value.

$$H_u = H_h - 2453 \cdot \left(W_r + 9 \cdot H_r\right) \quad \text{[kJ/kg]} \quad (1)$$

From the moisture content point of view wood chips are considered relatively in high water content. However, in rural areas were the consumtion of fuel wood is very high and the storage infrastructure is poor, it is expected that the water content of biomass for fuel purposes to reach higher values. Some agriculture waste result in high water content where from the analysis the below results were taken.

Moisture	W^r = 79,7 %
Ash	A^r = 1,21 %
Volatile matter	h^r = 19,09 %
Calorific value	H_u = 1,46 MJ/kg

Wet biomass is commonly found in many sectors in Albania. Particularly the olive processing industry, medicinal herbs sector, has shown key potential in biomass production for energy purposes. Thus, in recent years the olive processing industry has reached a significant increase. The amount of olive mill waste resulting from the respective companies operating in the market has significantly increased the capacities of wet biomass production. Currently for the drying of wet olive mill waste is used open sun drying process resulting in less cost for the end consumers. However, the increase of the demand for this product will lead to more energy intensity processes in this sector. A view of fresh wet olive mill waste is given in Figure 1.

Fig.1 *Typical wet olive mill waste in Berat, Albania.*

The moisture content of around 80% is related to the low calorific value of 1.46 MJ/kg, practically excludes the possibility of stand-alone burning.

***Table 2**. Chemical properties of different biomass type*

Chemical Analysis			Wood chips	Straw	Herbs
Parameter		Unit	Typical	Typical	Typical
Moisture	W_r	%.	20-60	7,7-23	10.5-21
Ash	A_d	%	0.3-6	2-7	3.8-8
Volatile matter	h_d	%	70-85	75-81	74-82
Calorific Value		MJ.kg^{-1}	5.9-15.1	11.8-16.1	11.1-15.2

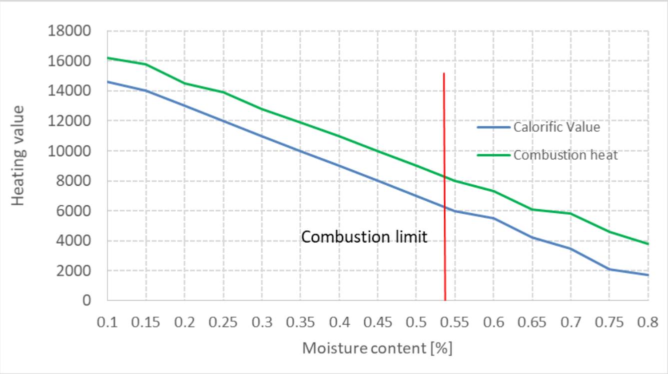

***Fig. 2** Relation of calorific value and heat of combustion to moisture content*

The reason for that is, of course, the large amount of heat needed for the evaporation of moisture from the biomass before ignition and also the large amount of water vapor in the combustion gases that are released in this case. Both of these influence on the temperature reduction in the combustion chamber below the permissible limit, which is necessary to ensure continuous combustion. The influence of the moisture content on the calorific power for wet biomass is presented in Figure 2.

At a moisture content of 55%, the calorific value is slightly above the limit of 6 MJ/kg, which can be estimated as the possible limit of the single burning of this biomass in the relevant energy technologies. From the graph, it is clear that with the decrease of water content, it is possible to obtain fuel with more calorific value, that is, better quality, regardless of the improvement of ignition and stability during its combustion process.

When the moisture drops below 35%, the biomass will have a calorific value similar to lignite coal, but with the advantage that it releases less SO_2 and ash residue. Fig. 3 shows the influence of moisture content on biomass for the theoretical flame temperature. Its calculation was carried out for excess amount of air α=1.3, for different preheating of air. From the figure it is clearly shown that it is not possible to use biomass with high humidity for combustion, because the flame temperature is too low. For temperatures up to 600^{o}C, flame ignition will most likely not occur. For slightly higher temperatures, up to 1000°C, the combustion would be very unstable and with a high CO content in the combustion gases.

From the graph, it is clear that with the decrease in humidity, it is possible to obtain fuel with more calorific power, that is, better quality, regardless of the improvement of ignition and stability during combustion. When the humidity drops below 35%, the biomass will correspond a calorific value similar to lignite, but with the advantage that it releases less SO_2 and ash residue.

Only after decreasing the flame temperature to approximately 1100 to 1200 ^{o}C, we can expect a stable combustion and almost perfect continuation of the burning mass. This adiabatic flame temperature corresponds to a moisture content of about 55%, which is consistent with experiences of burning wet fuels. The situation can be improved if we preheat the air to higher temperatures. Moisture content significantly affects the volume of combustion gases during biomass combustion. Figure 4 shows the dependence of the volume of combustion gases and water vapor in them, in relation to the water content of the biomass we are studying. Meanwhile, the volume of gases released during the burning of 1 kg of biomass decreases with increasing moisture, while the volume of water vapor in it increases. It is interesting to compare the volume of combustion gases for 1 MJ of calorific value. To achieve the required thermal power in the heat generator, it is important to add another amount of heat to the fuel. The quantity of this amount of heat depends on the efficiency of the heat generator, which varies slightly with the characteristics of the fuel, in this case the biomass. The relation of flue gas volume to water content if shown in Fig.4.

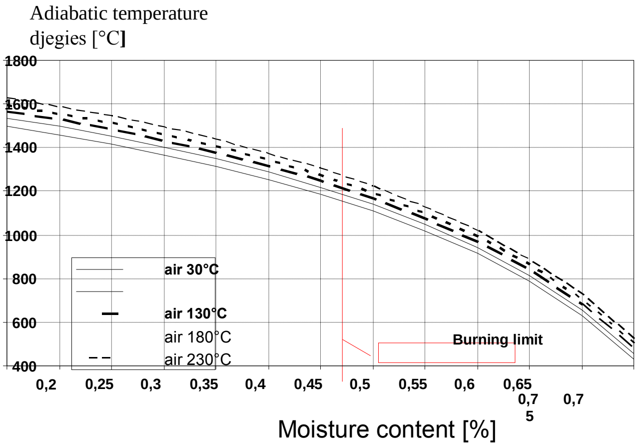

***Fig.3** Adiabatic temperature variation to moisture content and air temperature*

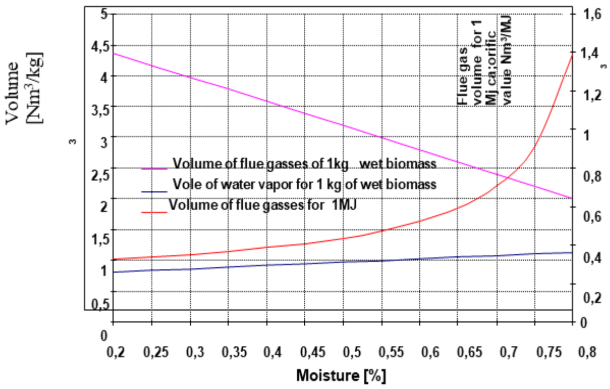

***Fig.4** Volume of flue gases and water vapor to moisture content of biomass*

Having this into consideration comes out that heat generators which burn drier biomass will release less combustion gases, so this heat generator will be smaller than those that burn wetter biomass. The graph in Figure 5 is presented the variation of water vapor saturation temperature in flue gases to moisture content of wet biomass. The excess amount of air is estimated α=1.3.

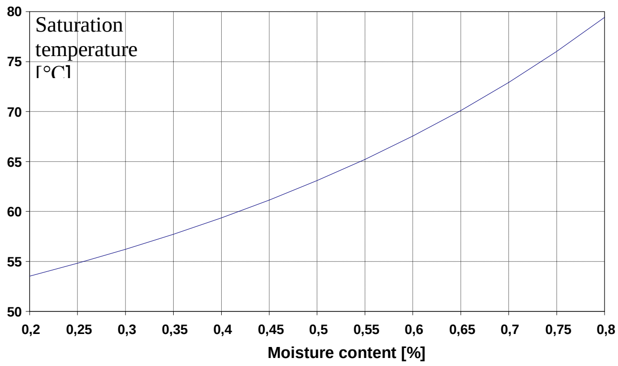

***Fig.5** Saturation temperature variation to moisture content of wet biomass.*

Another important aspect related to the moisture content in the biomass is the influence on the dew point temperature of the combustion gases. The temperature of the dew point of the gases corresponds to the saturated state of the vapors, thus the beginning of the condensation of water vapor in the combustion gases. Its scale is proportional to the content of water vapor in the gases, that is, the moisture content of the fuel. This is mainly divided by the temperature of saturated water vapor that responds to the partial pressure, although its real value is greater due to the presence of solids, mainly SO_2 gases in the combustion gases. In Figure 2 is shown the relationship between water vapor saturation temperature and biomass moisture (fuel), the actual dew point temperature would be 10 to 15 ^oC higher. Having into consideration that we do not want condensation on the end surface of the generator, we choose the temperature of the exhaust gases from the heat generator with a certain margin above the dew point temperature. From the above it follows that the cooling of the combustion gases and the use of heat in the dry biomass can be better than in the wetter biomass.

The content of combustion gases and the amount of water vapor in them affects the change in dew point temperature and losses in the heat generator chimney. The heat losses in the chimney, or in other words the apparent heat losses of the combustion gases, are the most important losses in the generator and significantly determine its performance. The method of their calculation is not the same. In order to express this the relation (2) is used in this case, where:

Z_m- the mechanical losses from unburned mass;

h_{gdj} is the enthalpy of flue gasses during the temperature t_0, and air excess α_0, after the heat generator;

h_{air}- is the outdoor air enthalpy;

$$Z_O = (1 - Z_m) \cdot \frac{h_{fg}^{t_0,\alpha_0} - \alpha_{fg} \cdot h_{air}}{Q_n} \qquad (2)$$

In Figure 6, is presented the relation between chimney losses to moisture content of the biomass. In order to estimate the other losses value is shown the relation with generator efficiency.

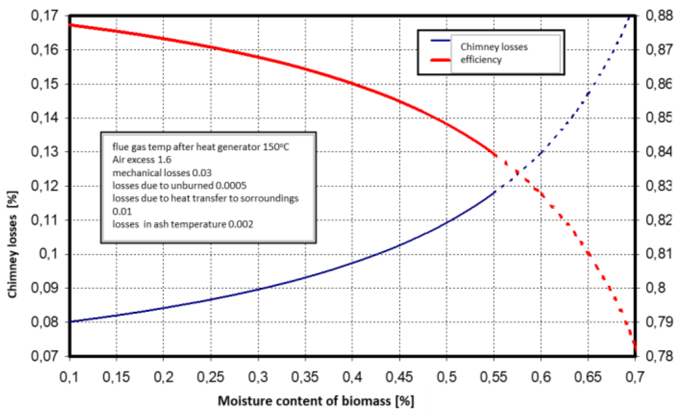

Fig. 6 *The relation between chimney losses, heat generator efficiency to moisture content of biomass*

From the graph above, it can be observed that for the same values of combustion gases and excess air, the efficiency of the generator progressively deteriorates with the increase of moisture content of the biomass product. The decline may reach several percent. The graph also shows the imaginary burning limit of biomass with 55% moisture content.

3. Drying of wet biomass

In order to utilize the wet biomass energetically it is necessary moisture must be removed before entering the heat generator. This can be achieved in two ways:

- Mechanical drainage;
- Drying, or the combination of these two methods.

Mechanical drainage of biomass can be carried out in many ways. The most widespread of them is mechanical pressing and centrifuge applying the centrifugal force on it. From the literature review it is obtained that the use of quality biomass presses leads to a moisture content of about 65%. These devices are of course expensive and the removal of moisture is found energetically difficult. The main reason why this high-water content biomass cannot be drained further is that the water is bound in the cells, where it can be released after the destruction of their walls. The drying of biomass in convective dryers utilizing hot air or combustion gases from different processes represents the most widespread method in the drying industry today. During the production of sawdust "pellets" or "briquettes" with this method, pre-heating is performed before the pressing process. Hot air-drying method has the advantage that the air holds more water than the combustion gases which are saturated with vapors from the combustion process. On the other hand, it is necessary to heat the air for drying in a special combustion gas-air heat exchanger or in steam heaters, which complicates and increases the cost of this method. Most industrial drying applications use combustion gases.

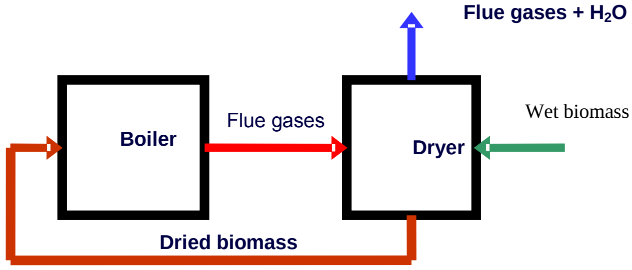

Fig. 7 *Principle of open convective dryer for wet biomass*

Drying of biomass with extraneous flue gases obtained by burning e.g. gas only for drying purposes is already well studied. Therefore, the attention will be focused primarily on convective drying with flue gases obtained by burning pre-heated biomass in a boiler that would produce steam for energy purposes. This variant corresponds to the common way of preparing fuel for combustion by drying its own flue gases in the so-called open circuit, where the dryer is integrated as part of the combustion equipment and partial or full flow of flue gas generated in the boiler by burning pre-heated biomass. The diagram is shown schematically in Fig. 7. The designation of the drying circuit as open means that the gases referred to as edges are removed from the dryer to the atmosphere and do not pass through the boiler. This has a favorable effect on the temperature in the hearth and the total volume of the generated flue gas will be smaller, however, the separation of the flight of solid fuel particles from the dryer must be addressed. The temperature of the drying biomass can be slightly high due to the high-water content in the material. It is important to observe the condition that the temperature of the drying medium behind the dryer (e.g. in the chimney) lies above the dew point temperature with a margin. The low temperature would lead to the condensation of water vapor on the cooler walls of the channels or in the chimney. In general, it can be said that the greater the drying and the smaller the flow of the drying medium, the higher the temperature will be needed after the drying process and also before the drying process. Experience with biomass drying shows that when drying to a moisture content lower than 30%, the temperature of the drying medium at the entrance to the dryer must be taken into account and chosen so that charring does not occur, i.e. partial gasification of biomass. If we were to answer the question of the drying temperature of raw wet biomass with the above-defined input moisture by the own flue gas, the following facts should be stated:

- The heat used in the boiler when burning wet biomass, regardless of their degree of drying, will be approximately constant and will depend only on the temperature of the flue gas behind the boiler or for dryness and excess air in the outgoing flue gas (relative to the minimum amount of combustion air).
- The flue gas temperature after drying will be the same in all cases, because the flue gas after drying will always have a humidity determined by the moisture of the wet biomass used. The dew point temperature of the flue gas will therefore be unchanged.
- A better drying scale will contribute to an increase in the temperature in the combustion chamber, which will simultaneously increase the temperature potential of the heat released in the boiler and thus improve the conditions for its use (smaller heat exchange surfaces for the same output), and also improve the conditions for ignition and burning of biomass in generally.
- A higher degree of drying will require a larger amount of heat for drying, i.e. a higher temperature of the flue gas taken from the boiler to the dryer. With a high initial moisture content of the biomass and extensive drying, this temperature may exceed the technically acceptable limit from the point of view of the safe operation of the dryer. This problem can be partially solved by recirculating the cold flue gas taken after the dryer to its inlet.

4. Conclusions

The promotion of renewable energy in Albania in recent has known significant progress, which includes various initiatives from high penetration of solar photovoltaic system, high efficiency cogeneration, energy efficiency in building, etc. Nevertheless, the country remains a large consumer of biomass for heating purposes. More than 50% of the population is using wood as fuel to meet their demand in winter period. This has created very strong relations between the community and the forests. For many years forests have been the main source of firewood causing unlimited use and degradation in specific areas. Therefore, wet biomass properties such as moisture content influence on calorific value was investigated in this paper. The results obtained demonstrate a combustion limit up to 55% moisture content in biomass. Another interesting result was the variation of chimney losses and efficiency compared to moisture content on biomass. The results obtained show significant drop on combustion efficiency with the increase of water content in biomass. The topic might be developed further in specific types of biomasses with high interest for the Albanian rural communities, especially in wood burning regions such as Korça. Investigation of firewood properties in non-conventional technology might be of great interest considering the energy efficiency of combustion techniques and environmental impact in this region where the intensity of biomass burning is very high. However, this issue might be the task for another study in near future.

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