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Biomass quality control in power plants: Technical and economical implications

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ABSTRACT

The consumption of forestry biomass for energy uses is a promising alternative to fossil fuels since it provides different environmental, economic and social benefits to the countryside. A cost-effective methodology is presented in order to establish the biomass price, consistently with its quality. The methodology commonly used in power plants is based exclusively on its estimated heating value, calculated from reference data and measured moisture content. This work analyses the economic benefits of using more accurate heating values determined from other biomass properties, thus requiring additional analyses. Results show that the biomass ash content is the most significant parameter affecting the heating value (a decrease of 760 kJ/kg has been obtained for an ash content increase of 3.7% with respect to reference fuel). The rest of parameters studied (harvesting season and biomass origin) lead to differences below 575 kJ/kg. Considering the increase in the fuel cost from additional analysis, the methodology based on measuring the higher heating value and the moisture content is the most appropriate technique to optimize the cost-benefit ratio of the plant. This technique is even more cost-effective when the frequency of analysis is reduced and the laboratory is shared with other plants from the same company.

1. Introduction

The scarcity of fossil energy resources, the instability of their prices and the environmental concerns (which have forced worldwide stringent regulations) have motivated researchers, governments and industry to find solutions to diversify the energy sources for power generation and to improve the efficiency of their management. Among the energy sources actually being promoted, the use of biomass (agricultural, forestry and industrial wastes as well as energy crops) as a fuel in power plants has several advantages, such as the economic and social development of the countryside, the removal of wastes and the reduction of CO_2 emissions. These advantages are especially important in Spain due to its high production of lignocellulosic biomass [1–3]. However, although European and Spanish energy policies [4] are encouraging the use of biomass for energy purposes, such policies have not been enough successful in Spain, owing to uncertainties in the guarantee of provision of raw material and to fluctuations of the raw material prize, and leading to the discouragement of investors. A great effort has been made to optimize all the steps involved in the biomass supply chain in order to improve the cost-benefit balance [1,5–7]. However, biomass quality changes are usual, leading to instabilities when compared to the expected profitability which have not been yet reported in the literature.

The methodology used in power plants to establish the price of a specific type of biomass is usually based on the fuel heating value. However, only the moisture content of the received biomass is systematically measured since it is the main parameter affecting the energy availability, the boiler efficiency and the combustion stability. The heating value is then estimated from the moisture content and a reference heating value. To select the latter, different data bases or equations proposed in the literature can be used [8–11], although it is previously necessary to define a reference composition. However, this composition (and thus the heating value) is affected by different factors, such as (in case of forestry biomass) the biomass origin (cutting, thinning, cleaning), handling (which could affect the ash content) and the harvesting season. Moreover, storage capacity has been proved as a necessary strategy to buffer supply shortages caused by climatic conditions and/or

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seasonal production, thus diminishing biomass supply chain risks [12]. During storage, the biomass quality can also change due to weather fluctuations and even to microbial activity. Thus, significant errors could be obtained when using the reference heating value. In order to avoid these errors and to guarantee an appropriate fuel price, further chemical analysis (ultimate, high heating value and ash content tests) would be required, which would increase the cost of the analytical tests (equipment and personnel needs) and thus the final economic balance.

This work studies the effect of different parameters affecting the biomass quality on the fuel Lower Heating Value (*LHV*) as well as the economical implications derived from considering different approaches to calculate *LHV*. Some quality-control methodologies different to that typically used in power plants have been evaluated in order to optimize the benefit-cost ratio. This evaluation is based on the comparison between the different estimated biomass heating values, as well as on the overcost required by each methodology when compared to the most economical one and to that used by defeat.

2. Methodology

The Low Heating Value (*LHV*) of a fuel can be calculated as shown in Equation (1) [13],

$$LHV_{p,ar} = \left[HHV_{v,d} - 212.2H_d - 0.8(O_d + N_d)\right]\cdot(1 - 0.01M_{ar}) - 24.43M_{ar} \quad (1)$$

where:

$LHV_{p,ar}$ is the Low Heating Value at constant pressure considering a moisture content M_{ar}, (kJ/kg, wet basis).
$HHV_{v,d}$ is the High Heating Value at constant volume (kJ/kg, dry basis).
H_d is the hydrogen content (% in mass, dry basis).
O_d is the oxygen content (% in mass, dry basis).
N_d is the nitrogen content (% in mass, dry basis).
M_{ar} is the moisture content as received (% in mass, wet basis).

The calculation of the different biomass physical and chemical properties shown in Equation (1) requires carrying out the following analyses:

- Biomass moisture content when received in the power plant (M_{ar}) [14].
- $HHV_{v,d}$: this value is determined from a calorimeter and from the moisture content of the biomass sample tested [13].
- Ultimate analysis: it allows for determining C_d (carbon content, % in mass, dry basis), H_d and N_d [15]. This analysis is required for the calculation of the oxygen content (O_d), which is then estimated by difference.
- Ash content in dry basis (Ad) by using a furnace and considering the moisture content [16]. This is necessary to improve the oxygen content determination.

The above mentioned analysis together with Equation (1) would allow the most reliable calculation of the biomass low heating value. However, the cost of these analyses would lead to an additional over cost caused mainly by the personnel needs. This work compares the low heating value ($LHV_{p,ar}$) obtained through the analysis above mentioned (which corresponds to the best estimation) with that obtained by using other control methodologies which require less significant personnel and equipments investments. The differences in the heating value have also been converted into fuel price differences in order to quantify the benefit-cost ratio of each methodology. The methodologies used have been the following and are shown schematically in Fig. 1 (notice that the measurement of the moisture content of the biomass as received is required for all the methodologies due to its significant effect on the fuel quality):

- Methodology 1: it assumes, as shown in Ref. [17], a reference and constant $LHV_{p,d}$ (Low Heating Value at constant pressure and dry basis) which is corrected after measuring the biomass moisture content when received at the power plant, M_{ar} (Equation (2)).

$$LHV_{p,ar} = LHV_{p,d}(1 - 0.01M_{ar}) - 24.43M_{ar} \quad (2)$$

This methodology is the one assumed by defeat in power plants as it is the one requiring lowest investments and because, as previously commented, the moisture content is the main parameter affecting the boiler efficiency and the power production.

- Methodology 2: it assumes, as also shown in Ref. [17], a reference and constant $LHV_{p,daf}$ (*daf*: dry ash free) which is corrected after measuring both, the biomass moisture content when received at the power plant (M_{ar}) and the biomass ash content (A_d, % in mass and dry basis). Equation (3) allows for the corrections above mentioned.

$$LHV_{p,ar} = LHV_{p,daf}(1 - 0.01A_d)\cdot(1 - 0.01M_{ar}) - 24.43M_{ar} \quad (3)$$

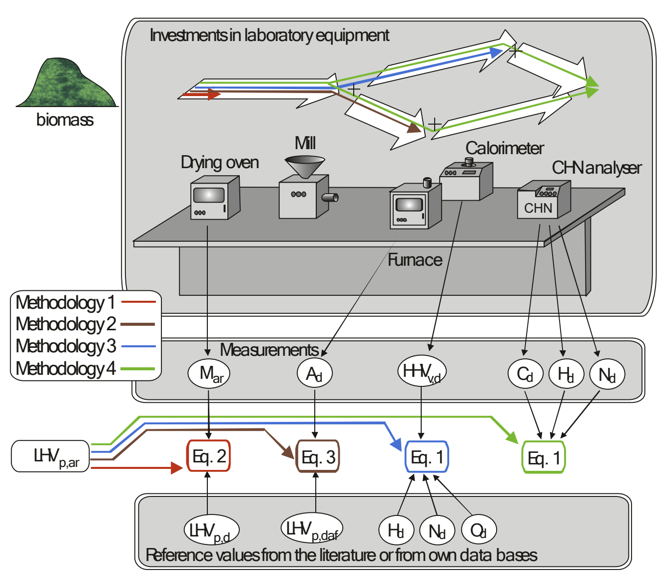

Fig. 1. Scheme of the methodologies studied.