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Mixed biomass pellets for thermal energy production: A review of combustion models

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HIGHLIGHTS

- The use of biomass is increasingly important for clean energy generation from renewable sources.
- An analysis of the current situation of the production of pellets (mixed biomass types) is provided.
- The main emphasis is on the review of different combustion processes.
- The evaluation of each individual stage of the combustion process is very important.

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ABSTRACT

The need to generate thermal and electrical energy, global warming caused by increased emissions of greenhouse gases, rising fossil fuel prices and demand for energy independence, have created a new industry focused on energy production through the use of renewable sources. Among the different options, biomass is the third most important source for obtaining electricity, and is the main source for the production of thermal energy. However, problems related to the low density of the different types of biomass, and the difficulty of transportation and storage, have led to the need to find solid fuels with higher density and greater hardness, known as pellets and briquettes. This paper seeks to develop an analysis of the current situation of the production of pellets, mainly with mixed biomass types, and the possible uses they have, with the main emphasis on the review of different combustion processes.

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1. Introduction

In recent times, humanity's development has been directly related to energy production, both for use as electricity and for thermal applications [1]. However, the increase in energy production has caused a considerable increment in the emission of greenhouse gases generated by fossil fuels such as coal, oil and natural gas. In fact, the production of CO_2 has grown from 4 million tons/year to more than 28 million tons/year over the past 60 years [2].

Due to high levels of CO_2, global warming and the rising cost of fossil fuels, the need to find clean and renewable new sources of energy has become imperative. This is reflected in the increasing investment in renewable energy projects all over the world [3]. This has allowed the creation and development of new technologies and new industries devoted to energy generation from renewable sources, representing presently more than 3% of the global energy produced from all sources [4].

Biomass comprises compounds resulting from photosynthesis processes and due to its carbon content it may produce energy by heat or chemical processes [5].

Among the main advantages of using this type of energy source are: the permanent availability with large amounts of biomass growing, low levels of greenhouse gas emissions produced by the processes of transformation and the low cost of recollection. It is possible to produce various types of solids, liquids and gaseous biofuels from biomass, such as briquettes, pellets, charcoal, alcohols, pyrolysis oils, biogas and biohydrogen, among others [6].

The main objective of this paper is to develop an analysis of the current situation of production of mixed biomass pellets (MBP), and their possible uses in thermal and electric energy production, with the main emphasis on the review of different combustion processes.

2. Pellets production

To evaluate biomass potential, it is necessary to consider several aspects. Among these are some physicochemical properties such as moisture content, carbon content, heating value and density, which are very important since they determine the use and the actual application that can be given to certain types of biomass [7].

By analysing the high heating value (HHV), it is possible to see how biomass can release large amounts of energy generated per kilogram of substance during the combustion process (Table 1), although these are slightly lower than those for coal. However, in order to make proper use of the different types of biomass and to take advantage of this potential energy it is necessary to take into account the density.

A substance with higher density and higher heating value has much more energy per occupied volume, which becomes one of the main features in the design of equipment for biomass energy usage [8,9].

It is possible to see that different types of agricultural waste [10] have similar heating values, between 12 and 18 MJ/kg, while pellets have slightly higher values (20 MJ/kg), making all of these substances potential sources for energy production, when compared with wood or coal.

Table 1
High heating value for several biomass forms and coal [9].

Fuel form	HHV (MJ/kg)
Wood	10–20
Vineyard pruning	14–18
Rice husk	12–14
Sawdust	12
Wood pellets	20
Coal	28

2.1. Biomass pellets industry

Pellets and briquettes are mostly solid cylindrical, differing solely in their dimensions. Briquettes have diameters between 50 and 90 mm and lengths between 75 and 300 mm, while pellet diameters are less than 10 mm with no more than 35 mm length [11].

To ensure pellet quality, there are currently several standards, depending on the country in which the solid fuel is produced. In Portugal, and in many other European countries, EN Plus is the relevant standard (Table 2), which evaluates the diameter, length, density, water content, ash content, high heating value, etc. [12].

Although developed from different types of biomass, the industry has focused primarily on the production of pellets from wood waste, to the point that countries like Sweden, Canada and the United States produce several million tons per year [13].

Pellets produced from wood waste are generated in order to produce electricity in cogeneration systems [14–17] as well as for residential district heating, and this currently represents a growing industry [18].

2.2. Biomass pellets production system

The pellet production process is based on a series of stages in which the biomass is treated so that compacted and densified material is obtained. The first stage is milling to obtain material with particles of equal size. The materials are subsequently dried and magnets are then used to remove the metallic elements present in the mixture. Once the material has been through these stages, it is moistened and pressed into a pelletizer machine, to lower the temperature and increase the hardness of the solid fuel [19,20].

Several studies have been performed on the different processing steps, of which the drying step is one of the most critical because of the large amount of energy consumed and the changes in the composition that may occur [21].

Drying processes with high residence times affect the amount of material present in the final pellets, by promoting terpenes evaporation, thus decreasing the heating value of the end product [22], and the use of gas recirculation systems in the drying stage of the process improves its efficiency by making it more cost-effective, since it reduces the total amount of energy required [23].

2.3. Mixed biomass pellets (MBP)

When pellets are produced from other forms of biomass than wood, they are called mixed biomass pellets, and mixtures of various agricultural and forestry wastes are being shown as having the possibility to produce solid fuels of sufficient hardness and resistance to transport, as well as heating values close to that of wood pellets [24,25].

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