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Investigation of woodchip quality: Relationship between the most important chemical and physical parameters

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A B S T R A C T

Considering the global warming and the climate change of the past few decades, European public policies have been established in order to increase the share of renewable energy sources. In the European context, one of the most interesting alternatives is woodchip. The present investigation provides an evaluation of woodchip quality underlining the relationships between the most important chemical and physical parameters, in particular between ash and some elements. Results highlight that the quality of woodchip is good even if some samples have very high ash content. Statistical analysis demonstrated that ash and moisture contents are highly linked to the net calorific value and a specific regression equation ($R^2 = 0.983$) has been identified. Considering the chemical characteristics, statistical analyses pointed out the correlation between elements and ash content demonstrating that the quality classes of woodchip can be reasonably divided based on ash content.

1. Introduction

Over the past few decades, the level of GHG (greenhouse gases) in the atmosphere has raised [1] causing global warming and climate change. One of the main important causes of GHG emission is energy production [2], which is expected to grow, considering also the continuous worldwide increase in energy demand [3]. The European Union is aware of the importance of finding new way of energy production and of the necessity to limit the dependency on energy imports to improve energy security. This aspect is complex and is influenced by increasing risks of supply disruptions due to a number of factors such as political turbulence, war, financial market turmoil, technical failures, unfavorable weather conditions [4].

Public policies have been set up in order to increase the share of RES (renewable energy source) to the electricity supply, including the target of 20% for the share of renewable in energy consumption in the EU by 2020. For these reasons, most focus should be given to RES for the generation of electricity and heat production.

Among the different types of renewable energy sources, wood biomass is one of the most promising alternative and with the greatest potential. It is available in many forms (dedicated and residual biomass) and in all parts of the world allowing the deployment of bioenergy almost everywhere [5]. It can be used to produce biofuels in solid, liquid or gaseous form and can be stored. Energy from biomass generally has limited weather-related dependencies and hence offers relatively constant and predictable energy output by comparison with wind and solar technologies [6]. Moreover, it is based on well known and proven technologies with good performance.

In particular, woodchips are an appealing alternative being a cheap fuel with low energy requirements for their production and with very stable burning or gasification due to their higher contact surface compared with other solid biofuels [2]. Different studies demonstrate that there is a gap between the amount of biomass resources for energy and the use of these sources; in fact, the energy use from biomass is less than the resources practically in all EU countries [7]. In Europe, Finland and Sweden use the largest volumes of forest woodchips, and it is expected that many other countries will increase the use of this solid biofuel to produce energy [7]. In Italy, although the electricity consumption is decreasing, the solid biofuel power plants for electricity production increased from 75 to 89 in the period 2012–2013. In the same period the CHP (combined heat and power) plants fueled with the same biofuel increased from 104 to 133 [8]. For some countries, like Italy, where the number of power plant is increasing the need to find new sources of supply could lead to a reduction in biomass quality for energy applications.

It is well known that woodchips and woody materials in general present a great variability of characteristics that leads to an

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indispensable need to employ quality standards to be fulfilled in order to drive the market in a sustainable way. The main international standard for solid biofuels is currently the EN-ISO 17225:2014, which defines different classes of products in relation to their quality. The quality of solid biofuels used for energy generation is defined by different physical and chemical parameters. In particular, one of the most important is the ash content representing a problem because of slagging in furnaces, fouling of heat exchanger surfaces [9], bed agglomeration, corrosion in the combustion device [10] and fly ash emission [11]. EN ISO 17225-4 is the quality standard for graded woodchip for residential, small commercial and public building applications and provides limits for three different woodchip quality classes. The most important discriminant between these classes is the ash content (A_c): classes A1, A2, B are related to a maximum A_c of 1.0, 1.5 and 3.0% respectively. Specific thresholds for elements are set only for B woodchip class.

The moisture content (M_c) is the most important physical characteristic of wood fuels, it depends on different factors [12] and it influences the calorific value. This parameter is a property of a fuel, which determines the energy value of it, and it is relatively constant for wood fuels in their dry status [13]. The contents of nitrogen, sulphur, chlorine and some minor elements are also important parameters for woodchip quality and can represent a burden especially for woodchip produced from crop residues [14].

Considering the raising interest on this solid biofuel, the goal of this paper is to evaluate the quality of woodchip available on the market and employed by Italian power plants. The investigation involved 1790 woodchip samples analyzed from Biomass Lab of Università Politecnica delle Marche. Within the data analysis, particular attention was given to the contents and indications of EN ISO 17225-1 [15] and EN ISO 17225-4 [16]. Moreover, considering the high number of biomass samples studied the paper aims also to investigate the possible correlations between parameters with special attention to net calorific value, A_c and M_c. To this aim, PCA (principal component analysis) was used in conjunction with conventional statistical techniques as reported by other authors [17].

A similar work was carried out by the authors on the wood pellet quality [18,19] but, as far as we know, no paper based on a comparable sample size are reported in literature for woodchip.

2. Materials and methods

During the years 2007–2013 chemical and physical analyses (Table 1) were performed on 1790 woodchip samples collected by the Biomass Lab of Università Politecnica delle Marche. The analytical methodologies adopted refer to the standards listed under EN 14961. The woodchip samples originate from power plants (district heating and combined heat and power plants) mainly during the application of a long-term monitoring of biomass quality employed in several installations. The high number of biomass samples comes from several part of Italy and the areas can be considered representative of the national scene for number and type of suppliers, origin and biomass typology.

2.1. Determination of net calorific value

Isoperibolic calorimeter (mod.C2000 basic, IKA) was used to perform the sample combustion under specific conditions in a bomb calorimeter. The calorimeter was calibrated with benzoic acid standard (IKA Benzoic Acid C723). The NCV (net calorific value) was determined by calculation from the gross calorific value, water and hydrogen contents of the analysis sample. These determinations were performed as well. The average NCV was calculated from two measurement series per sample.

2.2. Determination of ash content

A_c was determined using a TGA (thermo-gravimetric analyzer) (Mod. 701, Leco) by calculation from the mass of the residue remaining after the sample was heated in air under controlled conditions of time, sample weight and equipment specifications to a controlled temperature of 550 ± 10 °C using a muffle furnace. The percentage of A_c was determined by calculation from the mass of the remaining residue and the average A_c was calculated from two measurement series per sample.

2.3. Determination of moisture content

The sample was dried at temperature of 105 ± 2 °C in air atmosphere using forced ventilation oven (mod. M120-VF, MPM Instruments) until constant mass is achieved. The percentage of M_c was calculated from the loss in mass of the sample and is the average of two measurement series per sample.

2.4. Determination of carbon, nitrogen, hydrogen, oxygen

A known mass of sample is burnt in oxygen/carrier gas mixture, under such conditions that it is converted into ash and gaseous products of combustion. Oxides of nitrogen are reduced to nitrogen, and those products of combustion that would interfere with the subsequent gas-analysis procedures are removed. The carbon dioxide, water vapor and nitrogen mass fractions of the gas stream are then determined quantitatively. The combustion, the following separation by a gas chromatograph and detection of the elements were carried out by an Elemental Analyzer (mod. 2400 Series II CHNS/O System, Perkin Elmer, Waltham, MA, USA). Two determinations of carbon (C), nitrogen (N), hydrogen (H) per sample are performed. Oxygen (O) was calculated by difference.

Table 1
Chemical and physical parameters analyzed and corresponding reference methods.

Parameter	Unit	Normative references
Moisture content (M_c)	%[a]	EN 14774-2
Ash content (A_c)	%[b]	EN 14775
Net calorific value (NCV)	MJ kg^{-1}	EN 14918
Carbon (C), Hydrogen (H), Nitrogen (N)	%[2]	EN 15104
Sulphur (S)	mg kg^{-1}	EN 15289
Chlorine (Cl)	mg kg^{-1}	EN 15289
Minor elements (As, Cd, Cr, Cu, Hg, K, Mn, Na, Ni, Pb, Zn)	mg kg^{-1}	EN 14918

[a] Note 1: the percentage is a mass fraction of the sample as received.
[b] Note 2: the percentage is a mass fraction of dry matter.