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Energy recovery from cork industrial waste: Production and characterisation of cork pellets

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HIGHLIGHTS

- An alternative to the recovery of waste resulting from the cork industry is identified.
- The feasibility of obtaining a pellet with good physical and energetic characteristics is demonstrated.
- Pelletised cork waste has proven to be suitable for energy applications.
- Cork pellets have similar characteristics similar to forest waste, together with higher bulk density.
- Cork pellets also acquire transportation capacity, because of their low density.

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ABSTRACT

The cork industry presents itself as one of the most entrepreneurial in the Portuguese industrial sector, contributing significantly to the increase of exports. However, it is an industry in which the use of raw materials is maximised leaving a large volume of waste. The cork industry has tried to take advantage of these residues, mainly through direct energy recovery, despite the technical and safety difficulties presented by the use of such low density material, which complicates and hinders its transportation for industrial uses outside the area in which it is produced. The densification process opens new doors for such use and also for its storage, because it produces better results when compared with other more common products, such as wood sawdust or even forest and agricultural waste. Thus, cork pellets emerge as a safer and more easily transportable alternative for energy recovery from cork dust and other granulated types of cork waste, which offer the prospects for wider use. The results demonstrate that cork pellets have higher calorific value when compared with other biomass pellets; typically, approximately 20 MJ/kg with 3% volume of ashes, which is equivalent to that obtained from the combustion of pellets produced from combined forest and agricultural waste with a bulk density of 750 kg/m^3, which offers real advantages in terms of logistics.

1. Introduction

As economic and social evolution demands more energy, the lack of new sources of fossil fuels and the pollution that they cause, has led to a serious dilemma over environmental protection and economic development [1].

Since the world energy crisis of the 1970s, public and private decision makers have considered the possibility of achieving a transition from the current system based on fossil fuels to a more sustainable system based on clean energy. This new system is commonly referred to as renewable energy or green energy and might be the solution to the problem of the decline in the availability of fossil fuels, while reducing the emissions of greenhouse gases. This has now led to the development of some of these new energy forms with acceleration in their use over recent years [2].

Biomass is regarded as a source of energy that could play a key role in attaining the objectives set for Europe and Portugal with regard to the selection of new sources of energy, mainly for industrial use. Biomass could be one important energy source for two key sectors: electricity production and heating/cooling. The increased use of biomass is also an opportunity for reducing emissions of greenhouse gases, promoting regional development with the creation of new employment opportunities and reducing energy dependence on foreign countries [3].

The Portuguese government adopted the EU Strategy for the use of renewable energy following the dictates of Directive 2009/28/EC

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[4], transposed into Portuguese national legislation by Decree-Law No. 141/2010 [5], which stipulate that at least 31% of electrical power produced in Portugal, beyond 2020, should be generated from renewable sources [6]. Biomass has a very significant role in achieving this goal and several plants in operation by the end of 2012 will produce a total of 2500 GW h of biomass-fuelled electric and thermal power [7].

The use of biomass waste contributes to the share of renewable sources for energy production, reduces imports of fossil fuels and reduces the risk of forest fires [8]. In this context, biomass as a renewable energy source seem to be a promising option for improving the environmental situation, as it has several positive effects and the increase of its use is part of the political agenda of many EU member states [9].

Consequently, the Portuguese governmental strategy has set ambitious targets for using biomass for power and heat generation, which has resulted in a potential need for large amounts of biomass in the country [10]. Given the limited availability of residual forest biomass associated with the increasing production of biomass pellets in Portugal [11], already one of the leading European producers [12], once this industry has used large quantities of raw materials from the forest [13], interest in alternative forms of biomass increases, especially the waste from some industrial utilisations of biomass, such as cotton, paper and cork.

Portugal is well-known throughout the world as a producer of cork. It has always been linked to this activity and has been, in recent decades, the largest producer and exporter of cork. It is estimated that the area occupied by the cork oak (*Quercus suber L.*) worldwide is very close to 2.2 million hectares. This is largely distributed around the Mediterranean zone, especially in areas with an Atlantic influence, such as southern Europe and North Africa. The Iberian Peninsula has 56% of the total area (Portugal 33% and Spain 23%), three countries in North Africa have 33% (Morocco, Algeria and Tunisia) and Italy and France have a combined area constituting the remaining 11% [14].

The cork industry sector, apart from a socio-economic secular component, contributes to the mitigation of climate change effects in the Mediterranean basin, while it helps to protect biodiversity, representing a model of sustainability between human activity and natural resources [15,16].

Cork can be used as feedstock to replace other non-renewable materials, such as petroleum and its derivatives, which is now regarded as a luxury product and has applications ranging from textiles and footwear to nanotechnology. This proves that this forest-oriented industry, long ago abandoned the simple production of wine corks and champagne stoppers.

Forests in Portugal occupy about 39% of the total territory. Over the last two centuries the total area occupied by cork oak has increased significantly, reaching 23% of the total forested area [14].

Unlike what happens in clear up operations of forest areas occupied by other species, where waste is usually burned in situ and only occasionally used as fuel, the residues from clearing cork oak forests are usually collected and utilised, because of the high commercial value of cork and this helps to reduce the thermal load of the forest [17,18].

Traditionally, the cork industry has found uses for several cork by-products, including thermal energy recovery from cork dust, for which there is many other viable applications. However, its low density and volatility, leads to some technical and safety difficulties in terms of its energy use and there have been many cases of serious accidents in cork factories due to explosions and fires [19–21].

In Portugal, there is great experience in the production of wood pellets, especially regarding the use of indigenous types of wood, such as several types of pine (*Pinus pinaster* and *Pinus pinea*), eucalyptus (*Eucalyptus globulus*) and poplar (*Populus* sp.) [22], among others but also regarding the use of products of lesser economic importance, such as wood scrub resulting from forest clearing, cistus (*Cistus ladanifer*), gorse (*Ulex europaeus*), broom (*Sarothamus scoparius*), fetus (*Pteridium aquilium*) and brushwood (*Rubus ulmifolius*) [23].

In light of this and considering all the knowledge acquired in the densification of other forest products, further research in this area seems to be very promising for identifying an alternative to the recovery of waste resulting from the cork industry, allowing easier reuse and even the creation of a viable commercial alternative as an energy resource.

No previous references for this type of reuse of cork waste have been found in specialised literature, which is a new contribution of this paper.

Thus, the aim of this study is to pelletise and characterise a product made from industrial cork waste, demonstrating the feasibility of obtaining a pellet with good physical and energetic characteristics, demonstrating the logistical advantages of this densification and offering the possibility of using this form of biomass in other locations outside the cork industry.

2. The production of pellets

Internationally, biomass pellets are currently the most traded bulk biomass solid commodity for energy purposes. In terms of volume sales, this is about 4 million tonnes, which makes these products comparable to the volume of trade in biodiesel and bioethanol [24]. In Portugal, important levels of production capacity of biomass pellets began in 2005 and the largest industrial units started operating in 2008. Currently, 1.2 million tonnes of annual production is split between large and small producers who explore different markets, including exclusive exportation by large producers and the supply of the domestic market by smaller producers [25].

Pellet production represents the possibility of using different types of biomass waste, which includes cork waste, by transforming them into a product with more homogeneous and uniform characteristics. This allows its use in the boilers of domestic or services buildings, such as schools and hospitals, similar to what already happens with the waste forms used as raw material in pellet production burned in advanced industrial boilers [26]. Large scale industrial applications can be considered, such as thermal or electric energy production, co-firing or co-gasification with coal [27]. Other industrial uses are also possible. For instance, gasification of cork pellets can produce syngas, which is very important for industry as raw material [28]. Gasification is considered a key factor for promoting biomass energy and bio-liquid fuels use, which recently attracted increasing attention due to the advantages of high conversion efficiency [29].

The production of biomass pellets is a sequence of steps that includes: pre-processing, drying, grinding, pelletizing, cooling, screening and bagging and is described briefly in this work. Fig. 1 shows schematically a standard biomass pellet production line.

The need for milling during pre-processing depends on the condition of the raw material to be used, i.e., it is often desirable to homogenise and mix the materials before pelletising. The same concept is applied to drying. This step is of fundamental importance for final product quality, because a raw material in which moisture content exceeds 15% becomes very difficult to pelletise properly. The greater or lesser need for drying of the materials before pelletising is a key factor for the amount of energy expended in the production of biomass pellets. In the case of cork waste, drying is usually not required because its characteristic is to present very low moisture content (10–15%).