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Environmental performance of expanded cork slab and granules through life cycle assessment

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ABSTRACT

The great quantities of raw materials used in the construction sector, involve high energy consumption in their production resulting to a high energy use in this sector. One of the ways to improve the energy efficiency of buildings is through the use of more environmentally friendly materials such as forest-based materials. In the present study, the environmental impacts associated with the production of expanded cork slab and granules used in construction for insulation are evaluated from a life cycle perspective with the aim of identifying the most influential stages and processes. The obtained results show that the process with the greatest environmental impact derives from the boiler process due to the production of thermal energy used for the agglomeration of the slabs and also the production of *falca* used as raw material at the manufacturing process. It was also observed that the choice of mass or economic allocation has a significant impact on the results. The present study also considered the accounting of biogenic carbon in the climate change impact category which is usually considered neutral and excluded. The final results of climate change were recalculated by applying the International Reference Life Cycle Data System method for the stages of the forest, use and end-of-life. The consideration of biogenic carbon sequestration at the forest influenced significantly the environmental impact of the two products under study. The present study shows the importance of biogenic carbon inclusion in the environmental assessment of forest-based products. Additionally, the obtained results highlight the need for establishment of a common methodology for the calculation of the environmental impacts of cork products in order to apply common guidelines and facilitate the comparison of the obtained results.

1. Introduction

The construction industry consumes great quantities of raw materials involving high energy consumption in their production (Sieffert et al., 2014). The energy use of this sector accounts for a significant part of the world's total energy use (up to 40%) and the energy requirement for space heating and cooling of a building reaches 60% of the total energy consumed in buildings, representing the largest percentage of energy usage (Jelle, 2011; Kaynakli, 2012). Consequently, the need to improve the energy efficiency of buildings could be achieved through proper design and material choice for the insulation of the buildings in order to decrease the energy demands of the entire sector (Wright and Wilton, 2012; Zheng et al., 2010).

Considering the current increase of the environmental consciousness and general interest, the construction sector has shifted to the use of more environmentally friendly materials, such as natural materials, for various parts of the buildings, namely their thermal insulation, in order to decrease the environmental impact of the entire sector. Natural materials can be renewable (if they can be extracted more than once) or non-renewable (if they can be

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extracted only once) and they can potentially result in a more efficient building construction.

Natural materials include forest-based materials, such as wood and cork. One of the main advantages of using forest-based materials in construction is the carbon stored in them. More specifically, trees are known for their capacity to sequester carbon dioxide (CO_2) from the atmosphere and store it in their perennial tissues and in the soil as organic matter where it can be stored for very long periods (Linkosalmi et al., 2015; Martínez-Alonso and Berdasco, 2015). Thus, forest-based products contain part of the carbon that remains stored during their use period before being released at the end-of-life of the product (Dias et al., 2012; Dias and Arroja, 2014).

When assessing the biogenic CO_2 balance (CO_2 emissions and removals resulting from biogenic sources) in life cycle assessment (LCA) studies, the forest-based products are mainly treated as potentially carbon-neutral materials since it is considered that the amount of CO_2 sequestrated by the forest is then emitted into the atmosphere at the end-of-life stage of the product (Guinée et al., 2002; Althaus et al., 2009). Therefore, biogenic CO_2 sequestration and emissions are usually excluded from LCA studies, for example in the study of González-García et al. (2013) and Dias et al. (2014) for the production of raw cork. However, recent studies suggest that biogenic CO_2 should be taken into account in order to have a more complete view of the system under study and in order to avoid partial conclusions (Müller-Wenk and Brandão, 2010; Levasseur et al., 2013; Demertzi et al., 2015). Currently, there are several approaches to account for temporary storage and delayed emission of biogenic carbon, however there is still no accordance on the most appropriate (Brandão and Levasseur, 2010; Brandão et al., 2012; Garcia and Freire, 2014).

In the present study, two renewable natural construction materials are studied in order to evaluate their environmental performance through the use of LCA. This is a technique accounting for the environmental aspects and impacts of a product along its life cycle (i.e., raw material acquisition, manufacturing, use and end-of-life) (ISO, 2006a,b). More specifically, the materials under study are an expanded cork slab used in construction for thermal and acoustic insulation (main material) and expanded cork granules with acoustic insulation properties for use in screeds, flooring and interior cavity walls (coproduct). The main objective of the present study is to analyze the potential environmental impacts and identify the most influential stages and processes (hotspots) during the production of the two materials (used for insulation in construction).

A few LCA studies regarding the use of cork as construction material can be found in literature. For example, Boyer et al. (2009) and Mahalle et al. (2011) that studied agglomerated cork slab as flooring and Brito et al. (2010) and Pargana et al. (2014) that studied expanded cork slab and granules as insulation materials. The later compared various insulation materials for buildings besides expanded cork slab and granules (extruded and expanded polystyrene, polyurethane and expanded clay lightweight aggregates) in order to find the most environmentally efficient and concluded that both the expanded cork slab and granules present better environmental performances that the conventional insulation materials. Thus, their use for the insulation of a building can result to a lower environmental impact of the entire construction. Additionally, there is a study focusing on the production of Iberian cork from an economic and environmental point of view, presenting statistical information regarding this topic (Sierra-Pérez et al., 2015). However, the mentioned studies only present traditional LCA results and do not consider the biogenic CO_2 sequestration and emission. Thus, as a second objective, the biogenic carbon storage and emission delay at the forest (not only in cork but also in wood, roots and foliage), during the product's use and end-of-life stages is assessed by using a biogenic carbon accounting method, the International Reference Life Cycle Data System (ILCD) (European Commission, 2010), in order to evaluate its influence on the results obtained for the climate change impact category.

2. Methods

In this study, a cradle-to-gate approach is applied in order to assess the environmental impacts of the expanded cork slab and granules. Thus, the stages considering the extraction of raw materials up to the packaging of the final product ready to be sold are included in the assessment. Concerning the accounting of the biogenic CO_2 emissions, two additional stages are considered in the calculations, namely the use stage (considering 30 and 50 years of use) and end-of-life stage (considering incineration, landfilling and recycling as end-of-life destinations).

2.1. Product description and functional unit

The main product studied is an expanded cork slab, produced in Amorim Isolamentos S.A. in Portugal, used in construction for thermal, acoustic and anti-vibration insulation. Expanded cork slab is a 100% natural product since it only contains cork and no additional chemicals such as resins. Furthermore, it is a renewable and recyclable product with a very low waste generating manufacturing process. During the manufacturing process of the expanded cork slab, there is also the production of a coproduct that is studied as well, the expanded cork granules. This is also a 100% natural and recyclable product used as a solution of lightweight filling with thermal, acoustic and anti-vibration insulation properties. Some of the possible applications of this coproduct are for pitched roof with loose fill insulation between joists, filling of the internal double walls, rustic decorative floor, between joists loose fill, lightweight concrete-screed filling.

The functional unit (FU) is defined as 1 m^2 of insulation material with a thickness that gives a design thermal resistance (R) of 1 (m^2 °C)/W. Thus, based on the above definition of FU, the amount of insulation material (expanded cork slab and granules) that needs to be installed can be determined. Table 1 presents the specific characteristics of the expanded cork slab and granules (per FU) (as provided by the Amorim Isolamentos S.A. Company).

2.2. System boundaries

Fig. 1 presents the system boundaries for the production of the expanded cork slab and granules. The raw material, called *falca*, refers to fractions/pieces of 'virgin cork' (first bark grown in cork oak trees) that are extracted from the pruned branches of the living cork oak trees and/or from thinned trees (Pereira, 2007). This cork type, which is of low quality and cannot be used for the production of cork stoppers and thus, it is used mainly for the manufacturing of construction materials such as expanded cork slabs and granules for insulation. During *falca* production, the cork oak forest management processes such as fertilization, thinning and pruning, are considered. Furthermore, the transport of the pruned branches to the separation location (50 km) is also considered. At the separation location, the *falca* is separated from the wood and then the clean *falca* is transported to the manufacturing industry (30 km) in order to be naturally dried in the open air.

After an average period of at least 6 months, the dried *falca* is transported internally by a machinery to the trituration area. There the *falca* passes through a trituration machine, consuming electricity, and producing *falca* granules. Furthermore, in this stage, occurs a separation of the *falca* granules from impurities, such as small stones (moved to the landfill of the industrial area) and soil