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Environmental performance of a cork floating floor

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ABSTRACT

The objective of this study is to evaluate of the environmental impacts associated with the manufacturing process of a cork floating floor, produced in Portugal, in order to identify the most significant stages and processes (hotspots) with the aim of improving the manufacturing process and the sustainability of the product.

Life Cycle Assessment methodology is used by applying a cradle-to-gate approach. The results show that the stage with the highest environmental impact is the assembling stage (where all the product's components are assembled) mainly due to the production of high density fiberboard.

Additionally, the present study discusses the currently hot and controversial issue of biogenic carbon considering its storage in products and emission delay. For this part of the study a cradle-to-gate approach was adopted and three leading methodologies were compared, namely, Greenhouse Gas Protocol Product Standard, Publicly Available Specifications 2050 and the International Reference Life Cycle Data System. The results show that the choice of methodology has an important influence on the results obtained both for biogenic carbon dioxide emissions and carbon storage. This highlights the need for the establishment of a common methodology for the calculation of biogenic carbon, not only for the homogeneity of the guidelines but also for the ease of comparing results.

1. Introduction

Cork oak (*Quercus suber L.*) forests cover an area of 2,139,492 hectares, distributed in several European countries (Portugal, Spain, France and Italy), and Northern Africa countries (Algeria, Morocco and Tunisia). Portugal has the largest area of cork oak forest, about 736,000 hectares, representing about 34% of the total cork oak area. Cork oak is the second predominant tree species of the country, representing 23% of the total area of the national forest. Portugal is also the world's leader in raw cork production, contributing 100,000 tons of cork annually, corresponding to 50% of the global raw cork production [1]. The wine industry consumes the greatest part of the raw cork produced (70%) [1] but due to its versatility, cork has application in a wide range of sectors, such as construction (e.g., for flooring, insulation, core material, coatings and decorative objects), aviation, sports and automotive components [2–5].

The environmental importance of cork derives from the fact that cork oak forests can contribute to climate change mitigation since they absorb carbon dioxide (CO_2) from the atmosphere and store it in their perennial tissues and in the soil as organic matter. Carbon is thus retained for very long periods, as cork oaks are long-living trees (up to 200–250 years) [6]. Part of the carbon sequestered by cork oak trees is transferred to cork products. Consequently, cork products have the potential to mitigate climate change as well since they can stay in use for long periods, storing part of the carbon contained in the cork harvested from the forest and delaying its return to the atmosphere. Even cork products with a relatively short lifetime (such as 10–20 years) can store carbon for long periods when disposed in landfills at the end of their life, because under anaerobic conditions their decay is slow and incomplete [7,8].

Because of the relevance of the cork sector, it is important to evaluate the environmental impact resulting from its activities. This can be accomplished through the application of Life Cycle Assessment (LCA), a technique addressing the environmental aspects and potential environmental impacts throughout the life cycle of a product, from raw material acquisition through manufacturing, use, recycling and handling at the end-of-life (e.g., incineration and landfilling) [9,10]. LCA can be useful in identifying opportunities to improve the environmental performance of products at various points in their life cycle; in transporting the information to decision makers in industry, government and non-

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governmental organizations (e.g., strategic planning, priority setting, design or redesign of products or processes); in promoting the selection of relevant indicators of environmental performance including measurement techniques; and in marketing, such as implementation of eco-labeling, conducting environmental claims, or preparation of environmental product declaration (EPD) schemes [10].

A few LCA studies about cork and cork products can be found in the literature, evaluating different environmental aspects and impacts. There are examples of studies evaluating the environmental impact of raw cork production [11–13], cork stoppers [7,14–16], cork used as construction material, such as flooring [17,18] and insulation material [19,20]. However, most of these studies mentioned only present traditional LCA results and do not consider the biogenic CO_2 sequestration and emission.

There are some important issues to be considered when assessing the CO_2 balance of forest-based products. These products are mainly considered as potentially carbon–neutral materials since it is considered that the amount of carbon sequestrated by the forest is then emitted back to the atmosphere at the end-of-life of the product [21,22]. Therefore, traditional LCA studies often treat biogenic CO_2 emissions (emissions of carbon temporarily stored in biomass) by excluding them from the assessment. However, according to a newer insight, biogenic CO_2 should be taken into account in order to avoid errors [23,24]. On the other hand, even when carbon uptake during biomass growth is accounted for (as a negative emission) as well as the subsequent release (as a positive emission), the duration of storage is usually disregarded, i.e., the effect of delaying the emission of the temporarily stored carbon is not taken into account resulting in incomplete conclusions [25–28]. Even though there are various approaches to account for temporary storage and delayed emission of biogenic carbon [26–28], there is still no accordance on the most appropriate one.

The main objective of this study is to analyze, through LCA with a cradle-to-gate approach, the potential environmental impacts of a cork floating floor, used in construction, consisting of cork, high density fiberboard (HDF) and surface finishing. Furthermore, the present study aims to identify the most influential stages and processes (hotspots). Moreover, the biogenic carbon storage and emission delay during the product's use and end-of-life stages will be assessed by using different leading methodologies: the Greenhouse Gas (GHG) Protocol Product Standard [29], Publicly Available Specification (PAS) 2050 [30] and the International Reference Life Cycle Data System (ILCD) [31]. In this way, the influence of those methodologies in the results obtained, for the impact category of climate change, will be evaluated.

2. Methodology

2.1. Product description and functional unit

The product studied is a cork floating floor, produced in Amorim Revestimentos in Portugal. It consists of five layers (presented from bottom to top): cork backing layer, HDF layer, cork base layer, optic image layer and finishing layer. The cork backing layer has a thickness of 1.2 mm (mm) and offers impact sound reduction and thermal reinforcement. The HDF layer with a thickness of 6.0 mm offers more resistance and stability to the product. The cork base layer with a thickness of 3.1 mm offers step sound reduction, warmth and comfort, while the optic image layer with a thickness of 0.1 mm, provides a variety of visuals (imitating marble, slate, stone, metal, various textile surfaces and wood grain). Finally, the finishing layer with a thickness of 0.1 mm offers easy maintenance and extra wear resistance. The functional unit (FU) used in this study is 1 square meter (m^2) of final product.

2.2. System boundaries

The life cycle system is divided in different stages (Fig. 1), each one including several processes. Stage 1 represents the base layer manufacturing. This stage takes place in São Paio de Oleiros (northwest of Portugal). Firstly, the ''broken'' (cork resulting from the pre-trituration of ''falca'' that is low quality cork, extracted from the branches of the cork oak trees) arrives from the south of Portugal and it is separated from impurities, such as small stones. Then the ''broken'' is dried by heating it up to 60 °C (Celsius degrees) (depending on its moisture) in a dryer consuming thermal energy, and it is sent for trituration. The granules are then divided by granulometry and the granules of different sizes are stored in silos. The agglomeration process involves the blending of the cork with a resin. The mixture is placed on a conveyor and is pressed (applying high temperature and pressure) in order to be cut in slabs of the desired dimensions. After pre-sanding, the slabs are placed in an oven with controlled humidity and temperature for 255 min. After this operation, the slabs are put in stock (ambient conditions, not controlled) to stabilize for 10 days (minimum). After stabilization, the slabs pass through a sanding process. During this stage, electric and thermal energy are consumed. The thermal energy is produced by cork dust burning in an industrial biomass boiler (with natural gas as an ancillary fuel) and the electric energy comes from the national grid. The surplus cork dust produced at this stage is sold or given to other manufacturing units of the cork sector and other sectors (such as the ceramic sector) and it is not considered waste because it reaches the end-of-waste state (when a certain waste ceases to be waste and obtains a status of a product or a secondary raw material). The wastes associated with this process are stones, scrap, plastic and waste electrical and electronic equipment (WEEE) that only reach the end-of-waste state at the management operator. Thus, their transport is considered.

Stage 2 represents the backing layer manufacturing. The processes at this stage are similar to those of stage 1 but this stage takes place in a different industrial unit located in Lourosa (northwest of Portugal). In this stage, the agglomeration technology is different. The mixture of cork with the resin is placed in a metallic mold and by pressing and heating for some time, a slab is formed. Next occurs the bonding of two slabs in order to obtain the desired length that is then laminated to obtain a backing sheet of the desired thickness (1.2 mm). During this stage, there is use of electric energy (from the national grid) and thermal energy (from cork dust) as well. Moreover, there is water consumption for the cleaning of the equipment. The effluent generated in this process is sent for treatment in a waste water treatment plant (WWTP). The wastes produced in this stage are stones, raffia and scrap and their transport is considered, as referred above for stage 1.

Stage 3 represents the assembling of the product. This is the stage in which the assembling of all the main components of the product occurs through gluing and cold pressing. The glued and pressed component consisting of the base layer, the HDF layer and the backing layer is called ''sandwich''. For the assembling and pressing, electricity (again through the national grid) is used. This process requires water for the equipment cleaning and the water after use ends up at the WWTP.

Stage 4 represents the painting of the product. During this process varnish is applied to the product, in order to prepare the surface for printing, and also the printing operation occurs. All layers of varnish and printing are cured in ultraviolet (UV) tunnels.

Stage 5 represents the finishing and cutting of the product. This stage starts with the application of several layers of varnishes that are cured by UV tunnels. After finishing the application of varnish, the material goes to stabilization for at least 24 h and then moves on to the cutting process. In this process, the product is pre-cut and then cut according to the cutting profile of the fitting.