Environmental evaluation by means of LCA of champagne cork stopper production

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Abstract Cork is a natural and renewable resource that is extracted in the western part of the Mediterranean area and that is used to manufacture lots of products; one of them is the champagne cork stopper, which is a product made of two parts: an agglomerated cork body made from triturated cork and two natural cork discs made by punching. This type of stopper is mainly intended to seal champagne, cava, and other sparkling and carbonated wines. In this paper, the production of champagne stoppers was analysed from an environmental perspective, analysing their industrial cycle from the initial transportation of raw cork from the forest to the use of the products by consumers and waste management. This research is highly indicative of the state of the champagne cork industry because most of the worldwide production is concentred in Catalonia, where an industrial cork cluster is developing.

1 Introduction

Cork is a raw material completely natural and renewable extracted from the cork oak tree (*Quercus Suber*). Cork is obtained from the extraction of a thick bark of the cork oak tree. This species is endemic to southwest Europe and northwest Africa. Cork is composed of suberin, a hydrophobic substance, and it is a good material to produce several products because of its chemical and physical properties such as impermeability to liquids and gases, elasticity, compressibility, flexibility, fire resistance and so on [1]. In general two different types of cork

products can be found: a) natural cork products that are a group of applications that present a high added value and are made up directly of solid cork, and b) granulated-agglomerated products that have a lower value but are a profitable solution to take economical benefits from the huge amount of by-products generated during the production of natural cork products.
The best example of a natural cork product is the natural cork stopper[2], while some examples of granulated-agglomerated items are technical stoppers, floorings, building construction panels, acoustic insulators, decorative objects, shoes insoles, etc [3]. Also, cork is an interesting ecomaterial because it can substitute other non-renewable raw materials in different applications.
In the world, 2,277,700 Ha of cork oak forests exist, and the Iberian Peninsula concentrates more than 55% of them [4]. Moreover, 245.500 tons of raw cork material are generated in the Iberian Peninsula every year, concretely it represents 83% of the world cork production [5]. Cork can be extracted every 9 years in Portugal and Southern Spain, while in Northern Spain cork is extracted every 12-14 years because climatic conditions imply a lowest rate of growth of the cork oak tree. In addition to the supply of raw cork, other products can be extracted from these forests such as biomass, honey, mushrooms, medicinal herbs and other; however these products represent a lower economical value or are only extracted in little quantities. Furthermore, these forests are important because they provide other environmental functions such as prevention of desertification, conservation of biodiversity, carbon sequestration, wildfire prevention and so on [6].
Champagne cork stoppers are produced from an agglomerate cork granule body to which, on one of the ends, two cork disks are glued. This type of technical stopper presents a larger diameter than natural cork stoppers due to the fact that it is intended to put the top in gasified wine bottles with high internal pressures such as champagne, cava, and other sparkling and carbonated wines. This research is highly indicative of the state of the champagne cork industry because in 2009 Catalonia produced 60% of all cork champagne stoppers worldwide.

2 Methodology

The study applies the concepts of industrial ecology and life cycle assessment (LCA) methodology, according to 14040 ISO [7]. The present paper presents a gate-to-gate case study for the production of champagne cork stoppers by means of LCA. The system was carried out from the initial transportation of raw materials to the final management of wastes, including all the processes involved in the production.

2.1 Purpose of the study

The production of champagne stoppers was evaluated environmentally by means of LCA, accounting their industrial cycle from the initial transportation of raw cork from the forest to the production of the champagne cork stopper. The main specific objective of the present paper is determine which stages contributed most to the environmental impact of the champagne stopper production life cycle, in order to detect opportunities to improve the production technologically and especially from an environmental point of view.

2.2 Function and functional unit (FU)

The function of champagne cork stopper is to protect the content of a champagne or cava bottle of wine, preserving its quality and properties. One thousand champagne cork stoppers were used as functional unit (FU). The main characteristics of champagne cork stoppers are a length of 48 mm, a diameter of 30.5 mm, and a weigh of 9 g.

2.3 System description and boundaries of the system

The system covers the entire life cycle of champagne cork stoppers, excluding the forestry management stage because the aim of the study is the improvement of industries. Stages comprised in the system studied are reported in Figure 1.
After cork extraction from the forests, it is transported to the factories where the champagne cork stopper production system takes place. Then, the first stage is the preparation that corresponded to different processes to transform the initial tree bark into treated slabs useful to produce pieces of solid cork. There are different processes in this stage, but the first boiling that consist on a treatment of the slabs by immersion in hot water during 1 hour at 100ºC, and the classification of slabs into three groups are the most representative. From this stage resulted three types of raw material [3]: 1) cork slabs with a thickness higher than 27 mm, 2) cork slabs with a thickness lower than 27 mm and 3) cork slabs with defects, virgin cork, second cork, little pieces of cork.

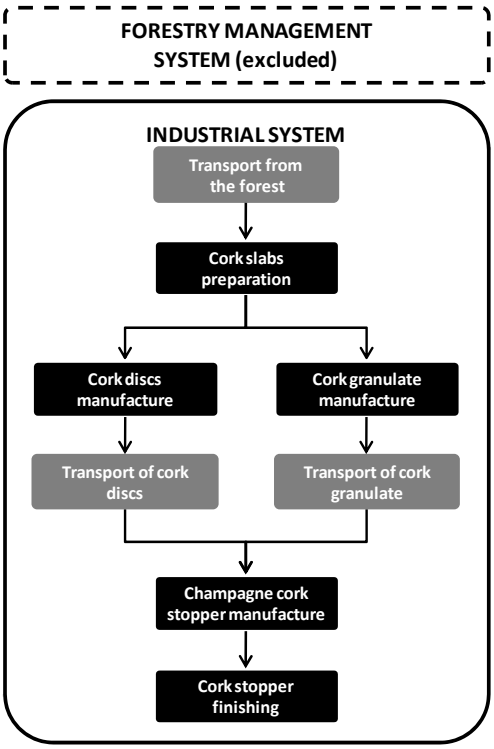

Fig.1: Champagne cork stopper production system

The first group is derived to natural cork stoppers industry, therefore this raw materials are not included in the current system, while the other two types of raw cork are send to the subsequent stages: cork disc manufacture and cork granulate manufacture. Both stages take place in parallel. The cork discs manufacture stage transform the slabs into solid cylindrical pieces of 34.5 mm of diameter and 6 mm thickness after different processes such as cutting the slabs into strips and into sheets, punching into cylindrical pieces and a quality selection of the best discs. On the other hand, cork granulate manufacture consists basically on the trituration of the raw cork into little particles between 0.25-8 mm, and later its classification in different sizes. Depending on the product that is going to be produced one or another grain size is selected.

When discs and granulates are obtained they are transported and the champagne cork stopper manufacture stage starts. It is frequent that specialized companies produce discs and granulates. Champagne cork stopper stage is composed for different processes such as granulates mixing, body agglomeration, polishing of the agglomerated body, glueing of discs, and finally homogenization.

Subsequently, champagne stoppers finishing stage ends the productive phase of the product. During this stage the stoppers are selected electronically and manually, later they are branded, surface treated with silicones and paraffins and packaged.
Transport to wineries and waste management was not included in the system because different assumptions and considerations must be done. Also, some aspects were excluded from the system such as the industrial buildings and machinery, administration and laboratory activities. In addition, wastewater was also excluded because at the moment there was no available data about their composition.

2.4 Data, software and allocation rules

Inventory data was calculated from the average of 5 representative champagne cork stopper companies. Each company provides all the data related to their production and this was subsequently averaged in order to obtain sector results and not individual data. The Catalan Cork Institute, an independent institution, revised all the given data. To complete the entire life cycle of the product, general data of the production processes (materials, energy and transports) was obtained from Ecoinvent [8].
The environmental analysis was developed using the software program Gabi 4.4 [9] and using the obligatory phases of LCA: classification and characterization. CLM 2001 method [10] for Abiotic Depletion Potential (ADP), Global Warming Potential (GWP), Eutrophication potential (EP) and Acidification potential (AP) was used to perform the environmental evaluation.
Allocation procedure was complex because raw cork materials of different origins were introduced to the system in different points of the champagne cork stopper life cycle production. Most part of them corresponded to by-products generated during the production of other products and sent to triturate to manufacture cork granulate, but some of them were generated into the same system and accounted previously. These by-products were allocated without any environmental burden because they must be accounted in the respective systems or in the respective point of champagne cork stopper production. Therefore, double accounting of impacts is avoided with this consideration.

3 Results

Table 1 presents the potential environmental impacts generated during the life cycle of champagne cork stoppers in terms of abiotic depletion, global warming, acidification and eutrophication. Also in the table, results for the best and the worst producer are reported in order to evaluate if there are differences among producers.

Tab.1: Environmental impacts associated to the production of thousand champagne cork stoppers

	ADP (1)	GWP (2)	AP (3)	EP (4)
Sector average	0.39	51.40	0.42	0.03
Best producer	0.34	36.62	0.30	0.03
Worst producer	0.43	59.83	0.48	0.04

(1) Abiotic Depletion (ADP) [kg Sb-Equiv.]

(2) Global Warming Potential (GWP 100 years) [kg CO2-Equiv.]

(3) Acidification Potential (AP) [kg SO2-Equiv.]

(4) Eutrophication Potential (EP) [kg Phosphate-Equiv.]

During the life cycle production of champagne cork stoppers 51.4 kg of CO_2 were emitted per thousand of stoppers produced. According to results, there are companies that produce the same emitting less than others. For example, the best producer generates the FU emitting 30% less of the sector emission; while the worst producer emitted 16% more. The range between the best and the worst producer is about 46%, this meaning that the worst producer has a significant leeway to improve their production from the environmental perspective. The same trend could be found for the other impact categories studied although the range is lower.

In figure 2, results are disaggregated by stages according to their contribution to the complete life cycle of champagne cork stopper production. The stage that contributes most is the champagne cork stopper manufacture, between 68-70%, depending on the considered category. Cork granulate manufacture contributed between 11 and 14% depending on the category. Some of the stages contributed very little; less than 2%; this is the case of the transport of the raw cork from the forest, the transport of the cork granulate and the cork slabs preparation stage. From an environmentally perspective, those stages that contribute more must be prioritized to be improved because it will contribute significantly to reduce the environmental impacts of the product, while changes in those categories that contribute less will mean an insignificant reduction of the environmental impacts.

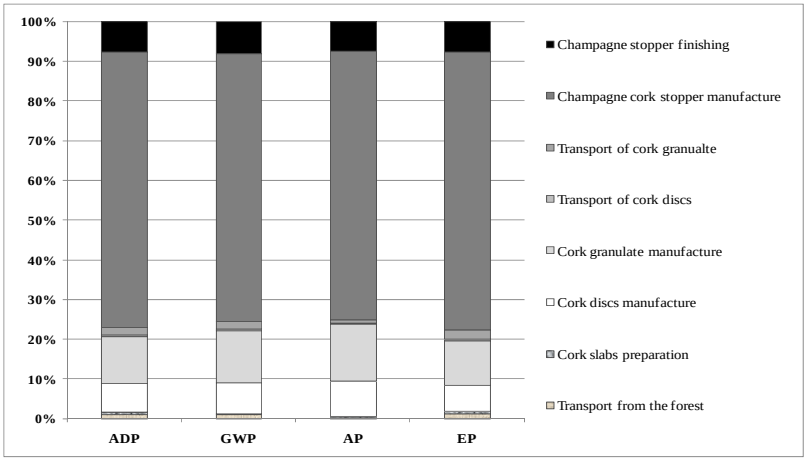

Fig.2: Environmental evaluation of champagne cork stoppers production by stages

During the life cycle inventory, it was stated that a lot of electricity was required to produce the FU and this flow is one of the main reasons to generate these impacts. The substitution of electricity and other non-renewable sources of energy could be a good strategy to reduce the environmental impact of the products, even if the substitution is done by renewable by-products generated in the production system such as cork wastes from the production or forestry biomass of cork oak forests. At the moment, only some of the studied companies start to implement this practice, but this practice must be more extended.

4 Conclusions

- It was found that 51.4 kg of CO_2 eq. was emitted to produce the FU: a thousand champagne cork stoppers.
- Some companies pollute most during the production of champagne cork stoppers than other. The best producer emitted 30% less CO_2 eq. than the sector average, while the worst emitted 16% more. The same trend is observed for ADP, EP and AP. These differences are indicative that present production of the worst producers could improve just implementing the technology that their competitors have already done.
- Champagne cork stopper manufacture was very clearly the stage of the production that contributed most, between 68-70%, to the overall impact of the product. Changes in this stage will contribute to reduce the environmental impact of the product very notably.

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