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# Environmental impact of oak barrels production in Qualified Designation of Origin of Rioja

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ABSTRACT

Ageing is a fundamental process and one of the most important steps in producing quality wine. In countries with a significant winemaking tradition, the maturation process usually takes place in oak barrels, due to their capacity to release compounds to the wine that enhance its properties.

This article presents a gate-to-gate life cycle assessment of the entire production process for barrels for the ageing of wine in Rioja Qualified Denomination of Origin (QDO). The life cycle assessment (LCA) was developed on the basis of site-specific data from a production plant over one year. A global analysis of the main phases of the production process shows that the process with greatest impact in almost all the categories analysed is the treatment of the wood (*Quercus petraea*, *Quercus alba* and *Quercus robur*). This is due to the higher demand for and consumption of energy resources at the wood cutting station in the production of the staves and heads.



## 1. Introduction

Ageing is a fundamental process and one of the most important steps in producing quality wine (Cernîşev, 2017; Gutiérrez Afonso, 2002; Ortega-Heras et al., 2004). The aim of this process is the maturation of wines to improve their sensory characteristics (Izquierdo-Cañas et al., 2016; Rodríguez-Solana et al., 2017), producing wines with more elegant colours, more complex aromas and finer flavours (Fernández De Simón et al., 2014; Panakhov, 2016; Prida and Chatonnet, 2010; Rosso et al., 2009). Wine can be aged in various types of containers, including stainless steel tanks, plastic tanks, oak barrels, and by using oak chips and staves (Canas et al., 2016; González-Marco et al., 2008; Sánchez-Palomo et al., 2017). In countries with a significant winemaking tradition, the maturation process usually takes place in oak barrels, due to their capacity to release compounds to the wine that enhance its properties (Garde-Cerdán and Ancín-Azpilicueta, 2006). The use of oak barrels for wine fermentation has a noticeable impact on the aromatic composition of the product (Cerdán et al., 2004).

Wines stored in barrels are constantly exposed to small amounts of air that penetrate by means of the porous nature of the wood, through the bunghole and through the seals between adjacent staves in the barrel (Del Alamo-Sanza and Nevares, 2014; Gómez García-Carpintero et al., 2012; Nevares and Del Alamo-Sanza, 2015), allowing the oxidation processes (Del Alamo-Sanza et al., 2017; Del Alamo-Sanza and Nevares, 2014) which are directly related to the wine's colour and other organoleptic characteristics (Ortega-Heras et al., 2004). Contact with the wood enriches the wine through the release of many volatile substances, enhancing the intensity and complexity of the wine's flavour (Pérez-Juan and Luque de Castro, 2014; Rodríguez-Rodríguez et al., 2012). The wood also releases some non-volatile substances that contribute to the wine's textural characteristics, such as astringency and mouthfeel (Petit et al., 2015). All of this greatly improves the wine's sensory characteristics.

The manufacturing of barrels has a great impact on the final characteristics of the aged wine, with the resultant effects on the wine's flavour, texture and aroma.

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The manufacturing process is extremely important and has a significant effect on the final characteristics of the wine during ageing. The seasoning of oak for winemaking purposes is intended to take advantage of climatological and environmental conditions to reduce its moisture content. From the perspective of the chemical changes to the wood, natural drying leads to a reduction of water-soluble polyphenols and more specifically of ellagitannins, which are strongly related to bitter flavours and astringent properties. It will also reduce the concentration of other volatile components associated with the development of vegetable aromas which are generally unwelcome (Moutounet et al., 1994; Saucier et al., 2006).

At the same time, natural drying increases the concentration of phenolic compounds (phenolic aldehydes and volatile phenols) and other volatile components (such as whisky lactone) related to the transfer of aromas from the oak (Mosedale and Ford, 1996; Mosedale and Savill, 1996; Pérez-Prieto et al., 2003).

Wine barrels are mainly produced from three types of wood from the *Quercus* genus (*Q. alba, Q. petraea* and *Q. robur*) (Baro et al., 2016; Guchu et al., 2006; Jarauta et al., 2005; Kozlovic et al., 2010; Rodríguez-Bencomo et al., 2009) because of their capacity to provide considerable aromatic richness to the wine during the ageing process. The choice of species depends on the desired aromatic and gustatory characteristics. The process for producing staves differs according to the type of wood used.

As the oaks grow in the forest, the growth rings developed in previous years cease to be active and these areas become heartwood. In parallel, the vessels which carried sap during previous periods become plugged, making the wood impermeable and able to hold liquid. The vessels of American white oaks become almost completely plugged, making the wood from these oak trees impermeable in all dimensions. This means that the trunk can be sawn in any position and impermeable planks will always be obtained. The trunk is usually sawn lengthwise to obtain the planks from which the final staves are made. The vessels of the European oak (including the varieties *Q. Peatrea* and *Q. robur*) do not become plugged in all dimensions, meaning that the wood will only be impermeable if cut in a specific position. Because of this, European oak for use in the wine industry is not sawn but split lengthwise, following the grain of the wood.

Once the staves have been cut, they must undergo a drying process to ensure that the wood can be adequately worked and machined, as well as to enhance its characteristics and eliminate the occurrence of undesirable substances during the ageing process (Masson et al., 2000).

Once the wood has been seasoned, the staves are used to create the barrel. During the assembly process, the wood undergoes a toasting process, to improve the wine's sensory attributes (Glabasnia and Hofmann, 2007). The type of toasting depends mainly on the desired sensory characteristics of the wine: light, medium or heavy (Rodríguez-Rodríguez and Gómez-Plaza, 2011). Many of the volatile components that form the basis of the oak aroma in wine are created during the toasting process (Collins et al., 2015). Other aromas, including vanilla and coconut, and smoky, nutty, earthy and fruity notes (Hale et al., 1999; Koussissi et al., 2009; Pérez-Prieto et al., 2003), are produced during the toasting process.

This paper analyses the environmental impact of the manufacturing process for barrels for ageing wine. While there are numerous scientific studies on the ageing of wine in barrels, there is no scientific literature on the environmental implications of the production process. This study aims to quantify the environmental impact of this process by means of a life cycle assessment (LCA). In order to identify and analyse the inputs and outcomes of the various activities involved in the process, we have developed a gate-to-gate model. The LCA is based on data obtained from a production plant within the Qualified Designation of Origin of Rioja, Spain, over one year of production.

Life Cycle Assessment is a commonly used tool in various fields of research, since it enables detailed analysis of the environmental impact of different products and processes (Carneiro et al., 2017; Leiva et al., 2015; Lorenz, 2014; Moore et al., 2017; Morris et al., 2015). Life Cycle Assessment is performed following the guidelines of ISO standard 14040 (Martínez et al., 2009) in order to analyse a product or process throughout its life cycle and determine its environmental impacts in the different impact categories defined at the outset of the LCA. To construct the LCA model, we analyse all relevant phases and processes involved in the product system under study and compile all the data from the input and output flows (Rebitzer et al., 2004) to create a Life Cycle Inventory (LCI). Using this model, we can carry out a Life Cycle Impact Assessment (LCIA) and develop various alternatives, modifications and optimisations to the initial basis. This enables us to analyse and evaluate the advantages or disadvantages of these changes (Garofalo et al., 2017) in terms of the product's environmental impact (Azzouz et al., 2017; Leiva et al., 2016; Wang et al., 2015). It is also a useful tool for decision-making (Notarnicola et al., 2012; Yang and Campbell, 2017) and environmental sustainability (Angelo et al., 2017; Cespi et al., 2015; Falcone et al., 2015; Wang et al., 2014).

## 2. Materials and methods

### 2.1. Objectives, scope and functional unit

The aim of this article is to describe a gate-to-gate LCA of the manufacturing process for a barrel for ageing red wine. To this end, all phases of the barrel manufacturing process are considered, starting from the delivery of the wood at the manufacturing plant. It includes all material, labour and energy inputs from the arrival of the wood at the plant to the final assembly of the barrel.

For the purposes of the LCA, the functional unit is defined as a standard six-hoop 225-L barrel for ageing wine.

Simapro 8.3 software is used to create the LCA model and CML-IA baseline V3.04/EU25 is selected as LCIA method. Selected impact categories are as follows: Abiotic Depletion (AD); Abiotic Depletion (fossil fuels) (AD-FF); Global Warming-GWP100 (GWP); Ozone Layer Depletion (ODP); Human Toxicity (HT); Fresh Water Aquatic Ecotoxicity (FWAE); Marine Aquatic Ecotoxicity (MAE); Terrestrial Ecotoxicity (TE); Photochemical Oxidation (PO); Acidification (AC); Eutrophication (EU).

Endpoint methodology, specifically ReCiPe Endpoint (E) V1.13, is also used in order to facilitate the reading of the results for comparison between the different varieties of oak analysed. Selected impact categories are as follows: Damage to Human health; Damage to ecosystems; Damage to resource availability.

### 2.2. System boundaries

Before carrying out the analysis, the limits of the system to be considered during the study (see Fig. 1) are established.

These limits encompass the production system for the creation of a functional unit, which includes the following activities:

- energy and electricity used in the normal functioning of the company's manufacturing systems;
- energy and electricity consumption of the rest of the facilities not directly linked to the manufacturing of the barrels (see Fig. 2, General consumption phase);
- materials consumed and emissions produced during the different manufacturing processes, including labour.