Journal of Cleaner Production 111 (2016) 172–180

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Improving environmental performances in wine production by a life cycle assessment analysis

Raffaele Iannone, Salvatore Miranda, Stefano Riemma, Iolanda De Marco*

University of Salerno, Department of Industrial Engineering, Via Giovanni Paolo II, 132, 84084, Fisciano, SA, Italy

ARTICLE INFO

Article history:
Received 23 December 2014
Received in revised form
3 March 2015
Accepted 2 April 2015
Available online 16 April 2015

Keywords:
Life cycle assessment
Red wines
White wines
Global warming potential
Process optimization

ABSTRACT

In the last years, the wine production industry had gradually focused its attention in the improvement of the product quality rather than quantity. This tendency generated an increase in the wine's price/litre, and, as a consequence, the entrance in the market of various small wine producers that developed new product trademarks of good qualities. The product quality obtained through better raw materials and more careful processes (with a semi-handcrafted quality) cannot be separated from an accurate evaluation of the environmental sustainability. Unfortunately, a higher number of small producers may generate greater emissions with respect to a small number of big industrial producers and, therefore, these small emerging productions have to be, even more so, studied.

The aim of this paper is to deepen the environmental impacts and the energy efficiency of four kinds of wines made by a small producer in the southern part of Italy using a Life Cycle Assessment (LCA) analysis. Vinification, bottling, packaging, distribution and waste disposal treatments were taken into account in the performed analysis. Wines were produced using different processes and different raw materials, depending on the specific characteristics (high or medium quality) and kind (red or white). The materials and energy consumption and the emissions to air, soil and water were reported to the chosen functional unit (a bottle of Italian wine). The data were analysed using SimaPro 8.0.2 software and the Ecoinvent database, in accordance with the reference standard for LCA (i.e., ISO 14040–14044) to identify the environmental performance indicators of the IMPACT 2002+ methodology. Once evaluated the global environmental impact on all the categories, we focused our attention and we proposed an improved solution in terms of global warming potential (GWP). In particular, for the red high quality wine (that was the most environment affecting wine), carbon dioxide emissions lowered from 0.99 to 0.05 kg_{CO2}/bottle.

1. Introduction

Carbon dioxide emissions reduction achieved a leading position in the last two decades research. Nevertheless considered “not dirty” if compared to chemicals and mining industries, the food industry is a large user of energy and, therefore, largely contributes to total carbon dioxide emissions (Roy et al., 2009). Environmentally friendly-products are approved with favour by the consumers (Barber et al., 2009) and local communities and governments encouraged the diffusion of environmentally relevant results. Some industries, like the one of wine, which environmental issues were for years unexplored, with the aim of improve market quota or consumer satisfaction, became among the most studied ones (Christ and Burritt, 2013; Rugani et al., 2013). Indeed, the cultivation of wine grapes and the production of wine are far from being environmentally clean processes (Gabzdylova et al., 2009).

Historically, the production of wine concentrated in Europe, in particular in France, Italy and Spain. According to the International Organisation of Vine and Wine (OIV), Italy is the second in a list of ten major wine producing countries, with more than 41 Mhl produced in 2011 (OIV, 2012), as shown in Fig. 1.

This work concerns the environmental impact and the energy efficiency of different wines produced in the southern part of Italy and exported in the whole country. A recent trend in the wine production industry led to the production of products of higher qualities rather than quantities; this tendency opened the market doors to small wine producers, which have developed good qualities wines on a small scale. Four main stages have to be considered in the production of wine: viticulture (related to vineyard planting and grapes cultivation), wine production and bottling (from

* Corresponding author.
E-mail address: idemarco@unisa.it (I. De Marco).

http://dx.doi.org/10.1016/j.jclepro.2015.04.006
0959-6526/

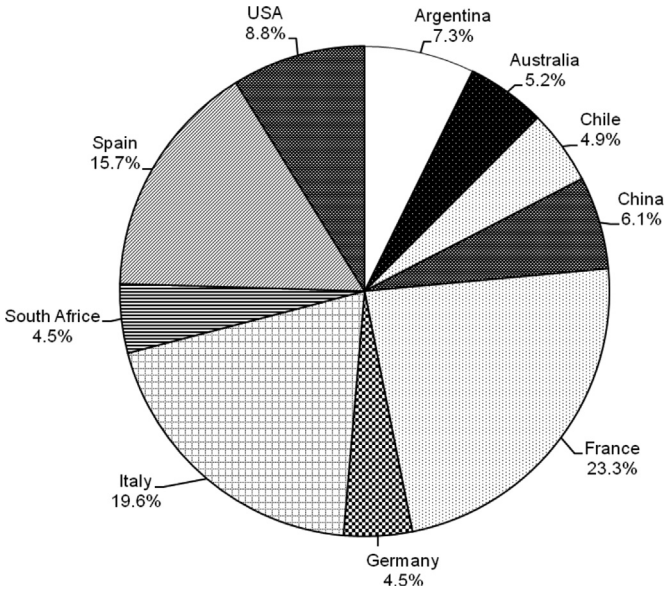

Fig. 1. Top 10 wine producer countries (data from OIV, 2012).

vinification to storage), wine transportation, distribution and sales, and disposal of empty bottles. To assess the environmental impacts due to the production of a bottle of wine, a Life Cycle Assessment (LCA) analysis can be used.

LCA is an internationally recognized and ISO standardized accounting tool to quantify the environmental impacts of a product, a process or a service throughout its life cycle, by identifying, quantifying and evaluating all the resources consumed and all the emissions and wastes released in an analysis known as a "from cradle to grave". In the last years, various LCA analyses have been performed in the case of agricultural productions, that are more complex because, for the agricultural phase, the LCA methodology is not well established, since the process cannot be easily standardised (Haas et al., 2000). Among the agri-food products, wine has been one of the most studied and several papers on LCA using a *cradle to grave* analysis have been published. In particular, Gazulla et al. (2010) identified the most critical, from the point of view of the environmental impacts, life cycle stages of a Spanish red wine production (starting from viticulture & grape growing phase) and compared its environmental performance with other wines and beers. Bosco et al. (2011) made a carbon footprint (life cycle of greenhouse gases emitted in the atmosphere evaluated in terms of global warming potential) analysis of four high quality wines produced in the Maremma Italian district, including all the products' life cycle stages, with a special interest on the agricultural phase (including also the vineyard planting phase). Point et al. (2012) used an LCA analysis to quantify environmental impacts for a bottle of wine produced in Nova Scotia, Canada, providing different scenarios in which lighter bottles or different transport modes and distances were considered. Fusi et al. (2014) performed an attributional LCA to deepen the assessment of the environmental impacts of a *Vermentino* white wine produced in Sardinia, Italy and exported all over the world. Amienyo et al. (2014) estimated the environmental impacts in the life cycle of a red wine produced in Australia and consumed in the United Kingdom. Other studies, like the one made by Ardente et al. (2006) or by Neto et al. (2013), used a *cradle to gate* approach, considering the distribution but not the waste disposal stage. Other studies considered the waste disposal but not the distribution (Pizzigallo et al., 2008; Iannone et al., 2014); other did not consider neither the distribution nor the waste disposal step (Benedetto, 2013). When in the aims of the work there is a decisional support, a *gate to gate* approach with the comparison of different scenarios was performed; in these cases, a single step of the process, that can be, for example, the viticulture (Vazquez-Rowe et al., 2012) or the end-of-life (Ruggieri et al., 2009) was studied.

The analysis of the state of the art underlines that a limited attention has been paid to the industrial wine vinification stages. Indeed, in most cases, the analyses made in the literature considered the industrial stages as a unique phase without details and deepening. Therefore, the step forward of this paper with respect to the existing literature is the in-depth analysis of the industrial vinification stages; i.e., preliminary phases, wine clarification, fermentation, cleaning, refining, bottling, distribution and end-of-life to verify the relevance of each phase on the total environmental impact in order to prioritize the powering up actions to improve the environmental performances. The results of the LCA analysis are related to the industrial stages of four different wines made by a small Italian producer.

2. LCA methodology

LCA is a multi-stage analysis in which a broad set of data, regarding the life-cycle of a product or a process, if properly collected and organized, are used to compare different products, different life-cycle of the same product or to individuate the most critical phase of a life-cycle from the environmental perspective. In the following sub-sections and paragraphs, the main steps that constitute the LCA methodology are presented: 1) goal definition, functional unit and system boundaries; 2) life cycle inventory; 3) Impact assessment; 4) Most affecting parameters evaluation.

2.1. Goal definition, functional unit and system boundaries

Goal definition is one of the most important phases of the LCA methodology, because the choices made at this stage influence the entire study. The purpose of this study is to estimate the environmental impacts and identify improvement opportunities in the life cycle of four different wines produced in Southern Italy: one Red of High Quality (RHQ), one Red of Medium Quality (RMQ), one White of High Quality (WHQ) and one White of Medium Quality (WMQ). The characteristics of the different wines are represented in Table 1. The analysis is focused on the wine production stages to highlight the different four wines environmental performances.

The definition of the functional unit (FU) is based on the quantity or mass of the product under analysis, and it is a reference unit to which all the inputs and outputs have to be related. The chosen FU was one 0.75 L bottle of wine produced by a small company in Italy instead of a 1 L bottle of packaged wine, since all four wines are sold in the same format of 0.75 L.

The system boundaries of the analysis, generally illustrated by a general input and output flow diagram, were set from grapes transportation to waste disposal. All the activities, the processes and the materials (included water and energy) used in the industrial wine production stages were taken into account. The proposal study does not refer to a "from cradle to grave" analysis, but to a "from gate to gate" and "from gate to grave" one regarding, in particular, the vinification, wine bottling and packaging, distribution and waste disposal. The viticulture was not included in the system boundaries because several papers have been already published on the LCA of these stages (Villanueva-Rey et al., 2014), whereas industrial phases in details received a limited attention. The transportation of the grapes to the winery was included into the boundaries, because the four kind of grapes came from different farms. Activities as the potential impacts regarding the consumption of refrigerated wine were not taken into account. Another