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Environmental impact of Sagrantino and Grechetto grapes cultivation for wine and vinegar production in central Italy

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ABSTRACT

The contribution of the European food sector to the total amount of greenhouse gases emissions is equal to one fifth. Footprint indicators together with Life Cycle Assessment have emerged to be useful tools to analyze and report environmental performance. In this paper the environmental impact of aged vinegar produced from Grechetto and Sagrantino grapes varieties is analyzed. Life Cycle Assessment of wine is performed to calibrate the model. Impact assessment is studied evaluating: carbon footprint, ecological footprint, water footprint, acidification, eutrophication, ozone layer depletion, photochemical oxidation. The new approach proposed in this paper leads to the obtainment of a complete analysis of the impact of aged vinegar, which can help a small farm choose more sustainable production methods, also optimizing logistics. This is the scientific added value of the work. The results show that aged vinegar has a carbon footprint comprised between 1.94 and 2.54 kg CO_2/l. The Ecological footprint of aged vinegar varies between 9.83 and 13.23 g m^2/kg. The Water Footprint of aged vinegar varies between 1332 and 1892 l/l. The water scarcity weighted water footprint methods available in the software SimaPro 8 give different results depending on their assumptions. These can be useful for comparative studies between different products.

1. Introduction

The contribution of the European food sector to the total amount of greenhouse gases emissions is equal to one fifth (Olivier et al., 2013). Footprint indicators together with Life Cycle Assessment have emerged to be useful tools to analyze and report environmental performance (Ridoutt et al., 2015, 2016; Sonesson et al., 2010). SimaPro software version 8 has come up with different indicators of water footprint sustainability. Despite this there is a huge debate between the LCA community and the water resources community on the possible integration of the water footprint in LCA software. As it is reported in Hoekstra (2016) water scarcity weighted water footprint approach is quite different from volumetric footprint, for the following reasons: the global scale of water scarcity; the scarce consideration of green water consumption; the fact that the WF of a project can be affected by the WFs of other projects; the fact that LCA treatment of WF is inconsistent with how other footprints are defined; the fact that Water Stress Index lacks meaningful physical interpretation. In this work both indexes are calculated: volumetric water footprint and characterized water footprint, following different methods available in the LCA software. They are applied to food production.

Italy in fact is the world leader in Protected Designation of Origin products. It has 283 products that are certified and protected by the European Union for their particular origin (166 PDO, 115 PGI, 2 TSG, according to MIPAF, 2016). Sagrantino is an Italian grape variety that is indigenous to the region of Umbria in Central Italy. It is grown primarily in the village of Montefalco and its surrounding areas, with only 250 acres (100 ha) dedicated to the grape in the hands of 56 producers (according to the website of Consorzio Montefalco, 2016). With such small production, the wine is not widely known outside of Italy, although it was granted DOCG status in 1991. Grechetto is a white wine grape variety of Greek origin. It is primarily a blending grape, though some varietal wine is also produced. In Italy, the Grechetto grape is found in DOCs of the central region, most notably Umbria's Orvieto region.

Among Protected Designation of Origin products obtained from grapes balsamic vinegar has now a magic moment. Sales increased

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Nomenclature

alfa	leaching-runoff fraction (−)
Appl	applied chemical rate (kg/ha)
C	concentration (kg/m^3)
CTA	consumption to availability (−)
EF	ecological footprint (−)
EQF	equivalence factor (−)
Et	evapotranspiration (mm)
K	coefficient (−)
LCA	life cycle assessment (−)
T	annual quantity of grapes produced (t)
WDI	water depletion index (−)
WF	water footprint (m^3)
WSI	water scarcity indicator (−)
WTA	withdraw to availability (−)
Y	world average grape yield (t/ha)
0	potential (−)
b	bue (−)
c	crop (−)
g	gray (−)
max	maximum (−)
nat	natural (−)
v	vineyard (−)
w	world (−)

12% in 2014 (ISMEA, 2012), reaching a production of 98 millions of liters and generating an income of 700 M€.

A distinction should be made on the two most important products; indicated as: traditional balsamic vinegar (certified DOP) and balsamic vinegar of Modena (certified IGP). Traditional balsamic vinegar is a homemade vinegar produced in Italy, by traditional method in surface culture fermentation. The raw material is cooked grape must, having a content of soluble solids (above all glucose and fructose) ranging from 20 to 60°Bx and pH values of 2.3–3.2 (Solieri et al., 2006). As with other vinegars, it is obtained by a two-stage fermentation process. The minimum aging period for traditional balsamic vinegar is of 12 years (see Gullo and Giudici, 2008). Respect to the traditional balsamic vinegar the balsamic vinegar of Modena is obtained mixing different percentages of vinegar and cooked must. The aging period is very short (the minimum is 60 days), compared to the 12 years required for traditional balsamic vinegar. In this work a production process is proposed, which is similar to that used for balsamic vinegar of Modena, but applied to another region in Italy, for this reason the product is not addressed as balsamic vinegar but aged vinegar.

Consumers are very attentive to the sustainability of the food they buy, 80% of them are willing to pay more money to have wine produced in an environmental friendly way (see Lockshin and Corsi, 2012). For this reason TESCO has measured several Carbon Footprints of the food it sells as reported in Fantozzi et al. (2015). Vázquez-Rowe et al. (2013) have analyzed 9 carbon footprint studies on wine in three European countries, using the same methodological assumptions. Lamastra et al. (2014) have analyzed a new approach to assess the water footprint of wine in Italy, while Niccolucci et al. (2008) calculated the ecological footprint of organic and conventional wine. Neto et al. (2013) performed a Life Cycle Assessment on the supply chain of a Portuguese wine, from viticulture to distribution.

No carbon footprint, water footprint, ecological footprint or LCA analysis has been ever made on aged vinegar. For this reason a farm in Umbria, central Italy, decided to set up a decentralized line for the production of its own aged vinegar and to calculate its environmental impact testing different indicators (Water Footprint, Water Footprint Sustainability indicators, Ecological Footprint, Carbon Footprint and the LCA indicator EPD, 2013 of the software Simapro). To test the analysis, results obtained for wine and grapes (which are ingredients in aged vinegar production) are compared with the above cited literature studies. Two production chains are tested: in the first Greghetto grapes are transformed in a cooperative winery near the farm, while in the second Sagrantino grapes are transformed inside the farm.

The novelty of the study is represented by the product (aged vinegar) and by the approach of the study, which evaluates a huge range of indicators to give the most complete idea of the environmental impact of the product. This represents the most important scientific value added of this paper. Starting from the presented results, farmers can reduce the burden linked with their production, through the use of renewable energies and agro-energy districts designed with adequate Decision Support Tools (see Lacquaniti and Sala, 2009; Manos et al., 2014; Fantozzi et al., 2010). The presented results can guide investors, businesses, public sector policymakers and even consumers of everyday goods and services in making decisions which lead to a better environmental outcome. Results can be presented to consumers to improve their behavior and also to manufacturer to promote design for sustainable behavior (DfSB), see Polizzi di Sorrentino et al. (2016). Particular attention should be kept at minimizing food wastes during the supply chain, according to Mirabella et al. (2014) and Papargyropoulou et al. (2016).

2. Materials and methods

In the section about material and methods the goal and scope of the Life Cycle study is introduced, identifying the functional unit of the study, the boundaries, life cycle stages and Product Category Rules (PCRs). The meteorological data used in the calculation of green Water Footprint will also be shown. They are taken from a meteorological station belonging to the Italian Central Office of Agricultural Ecology (UCEA) and they refer to the growing season 2012. In the goal and scope of the study also the norms which refer to carbon footprint, water footprint and LCA are reported, which are respectively: ISO TS 14067 (2013), ISO 14046 (2014), ISO 14040 (2006a) and ISO 14044 (2006b). Finally the calibration of the model is presented, results calculated for wine and grapes life cycles are compared with literature data.

2.1. Goal and scope of the study

The Functional Unit of the study is represented by 1 l of produced material. All the calculations are referred to the growing season 2011/2012. Cultivation operations for the vineyard are reported in a registry, used during monitoring operations. Both direct emissions and indirect emissions are taken into account in the study. Direct emissions are defined as those generating from the use of the energy vector, indirect emissions are those generated by the production of the energy vector, as described in the ISO 14064 (scope 1, 2 and 3 emissions) – see ISO (2006c), ISO (2006d), ISO (2006e). Electric