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Life Cycle Assessment For Packaging Of An One Bottle Of Wine

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***Abstract*—Food production has one of the main impacts on global warming. Because this sector needs to occupy terrestrial land and use water in high quantities. Besides that, the food sector is responsible for nearly 29% of anthropogenic greenhouse emissions. The study aimed to compute the carbon footprint of one bottle of wine was 750 mL volume. With this purpose, Life Cycle Assessment was carried out by using CCaLC2 software for the approach of cradle-to-grave. Data was taken from the previous literature research. For computing the carbon footprint of the process, raw materials and requiring energy input amounts, production and transportation steps, and recycling information defined in CCaLC2 software. In this study, it was enlightening which of the steps contributed to CO_2 emission more growing of grapes in a vineyard to an end-of-life wine bottle.**

Keywords—carbon footprint, sustainability, life cycle assessment, recycle

I. INTRODUCTION

Global warming is a situation that poses a threat to our planet. Global warming means increasing the surface temperature of the earth because of increasing the amount of some gases. These gases are called greenhouse gases (GHGs) which are carbon dioxide (CO_2), steam (H_2O), methane (CH_4), chlorofluorocarbons, nitrous oxide, and ozone. The reason for global warming is mainly based on human activities [1].

CO_2 comprises 65% of GHGs that are released throughout the world. The United States contributes CO_2 by 16%. China is responsible for 30% of the global CO_2 emissions [2]. So, the researchers have developed some strategies to use, store, and capture CO_2 emissions [3]. Reducing fossil fuel-based CO_2 is accepted as the logical way to use natural gas. Using biomass instead of fossil fuels is another way to reduce CO_2 release [4]. Hydrogen production from biomass, a hot topic studied these days, is crucial to reach clean fuels [5-7]. However, there are some drawbacks to using hydrogen as a fuel. Because it is hard to store and produce hydrogen [4]. CO_2 is a cheap, non-toxic, non-flammable gas. However, it needs to use catalysts, reactive chemicals, and high energy to use CO_2 in several reactions. Because CO_2 tends to stay stable in a reaction medium [3,8].

In the food industry, a high amount of energy is used. So, a high amount of GHGs released because of this energy utilization. With the increase of awareness of food consumers throughout the world, it has occurred necessary to produce food in eco-friendly ways [9].

In wine packaging, several alternative packaging materials are possible such as aseptic carton (AC) and polyethylene terephthalate (PET). These alternatives developed because of the high price of the as-said materials and the heavy and rigid nature of glass. Concerning sustainability, glass accepted the worst packaging. However, it can be possible to low environmental effect on this material. Since the glass recycling rate is around 60%. Besides that, reusing glass is a logical solution to this situation [10].

Life Cycle Assessment (LCA) is a methodology by which it can be possible to obtain the environmental impacts of a product throughout its life cycle. Using this methodology, the producers must generally know the quantity of the consuming resources (raw materials and energy) and occurring wastes during the processing time of product evaluation and disposal [11].

In the scientific literature, there are several studies about the LCA of glass bottles used in beverage packaging in literature. In the previous studies, researchers compared glass and PET materials using mineral water [12] and milk packaging [13], olive oil [14] and studied reusable glass beer packaging [15].

In this study, the aim was to show the effect of raw materials, manufacturing, delivering, and waste management strategies of one bottle of red and white wine on the environment for the amount of GHGs emissions by using an LCA software tool. The data possessed by the wine production, delivery, and disposal were taken in the previous research and were adjusted and modified for the software. The software displayed GHG amounts on a CO_2 based.

II. MATERIAL AND METHODS

The software which was used in the calculations was CCaLC2. This software was developed by The University of Manchester in 2015.

In this study, it was considered only the effect of the wine bottle and cork on carbon footprint. Firstly, the functional unit was defined as a 0.75 L bottle that can be used for packaging red or white wine. Bottle and top (cork) materials were shown in Table I. These materials were selected concerning the software. Bottle and top weights shown in Table II. These values were taken in the previous research [16].

During bottling, the producers use steam and electricity. The values were given in Table III. It was assumed that the water source was Spain based and the electricity source was European quality.

Transportation uses to transfer the bottles abroad. For this purpose, manufacturers benefit from trucks and ships. In Table IV, this information was given for bottling materials transportation for one bottle of wine. In the cited study, researchers worked on 16 and 40-t trucks, however, the author used 22 and 40-t trucks. Because, in the CCaLC2, there was no information about the 16 t truck yet.

The waste management strategy for the wine packaging materials were presented in Table V. So, the top material is landfilled completely. However, glass wine bottles can be recycled substantially instead of landfilled wholly. The percentage amounts can be considered mass-based.

TABLE I. MATERIALS FOR PACKAGİNG A BOTTLE OF WINE

Description	***Wine Type***	
	Red	***White***
Bottle	Glass-bottle (virgin)	
Top	Wood-pine timber	

TABLE II. WEIGHT OF PACKAGING MATERIALS

Description	***Wine Type***	
	Red	***White***
Capacity (litres)	0.75	
Weight of bottle (kg)	0.43	0.12
Weight of top (kg)	0.015	
Bottle weight per functional unit (kg per 0.75 L)	0.573	0.16
Top weight per functional unit (kg per 0.75 L)	0.02	
TOTAL weight per functional unit (kg per 0.75 L)	0.593	0.18

TABLE III. ENERGY USING FOR BOTTLING [16]

Source	***Value***
Process water-Spain-Blue water (litres)	0.6
Electricity (high voltage)- european grid (kWh)	0.011

TABLE IV. TRANSPORTATION INFORMATION [16]

Vehicle	***Distance (km/ton)***
40t truck	1.43
22t truck	0.37
Container ship	0.06

TABLE V. WASTE MANAGEMENT INFORMATION [17]

Type of Waste Management	***Bottle (%)***	***Top (%)***
Recycling	70.70	-
Landfill	29.30	100
Incineration	-	-

III. RESULTS AND DISCUSSION

A. Carbon Footprint for Red Wine Packaging

For a one-bottle red wine, the effects of the materials on CO_2 emissions are shown in Fig. 1. Considering this result, it concluded that glass was responsible for the CO_2 release mainly. Pine wood's effect on global warming was low. Fig. 2 it presented the effects of using water and electrical energy in the wine bottling step on CO_2 emissions. At this step, it assumed that using waste process water was treated before its draining, or reused in the plant. So, the treatment was also the effect of global warming. Besides that, it seemed that the energy used for wastewater treatment was higher than used electrical energy in one bottle of red wine production.

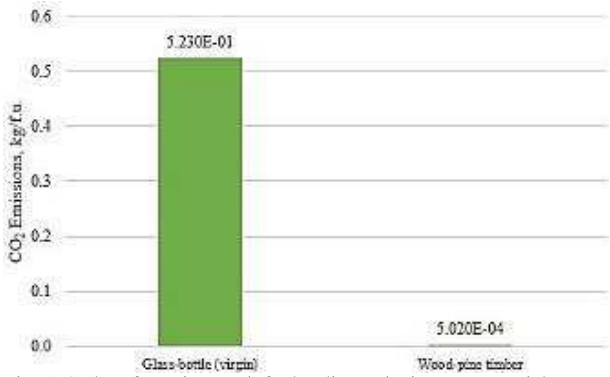

Fig. 1. Carbon footprint graph for bottling red wine raw materials

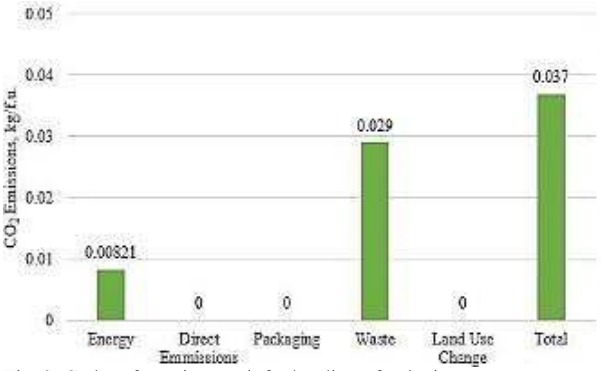

Fig. 2. Carbon footprint graph for bottling of red wine

In Table VI, it can be shown the effect of one bottle of red wine transportation abroad on CO_2 emissions. So, the transportation effect was quite low compared to raw materials production and the process of bottling. Also, it should be thought that these calculations were based on one-bottle transportation. So, it is expected high amount of CO_2 occurs when the number of bottles in vehicles increases. In Fig. 3., waste management strategies of the glass and top on CO_2 amount were presented. So, the releasing GHGs from the landfilling of wood products was high compared to

landfilling glass and disposal of glass to recycling plants. As a result, the total GHGs emission amount for one bottle of red wine was found as 0.604 kg CO_2 eq./functional unit.

TABLE VI. CARBON FOOTPRINT RESULTS FOR TRANSPORTATION OF RED WINE

Material Transported	*Transport Type*	*CO_2 eq. (kg/f.u.)*
Glass-bottle (virgin)	40t truck	$4.02*10^{-9}$
	22t truck	$2.05*10^{-8}$
	Container ship	$1.82*10^{-10}$
Wood-pine timber	40t truck	$4.89*10^{-12}$
	22t truck	$2.50*10^{-11}$
	Container ship	$2.21*10^{-13}$
	Total:	$2.47*10^{-8}$

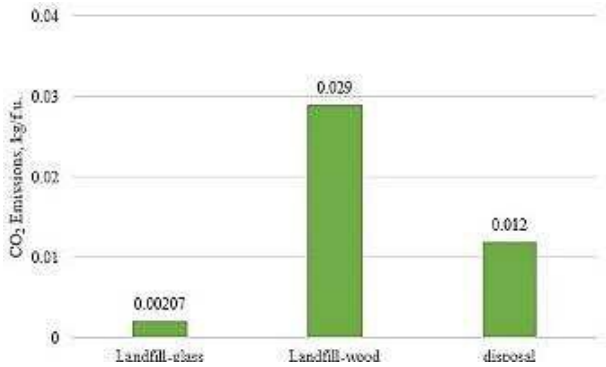

Fig. 3. Carbon footprint graph for waste management of bottling red wine raw materials

B. *Carbon Footprint for White Wine Packaging*

For a one-bottle white wine, the selected material's effect on CO_2 emissions was shown in Fig. 4. Regarding this result, it can be concluded that glass was responsible for the CO_2 release mainly like red wine raw materials. However, differ from red wine; the GHG emission from the glass was low. Because the amount of the glass which was used in white wine packaging was lower than the bottle weight of red wine. Using electrical energy and water was the same for the two wines. So, the graph was not drawn again for the wine bottle. Table VII, it was shown the effect of one bottle of white wine transportation abroad on CO_2 emissions. So, the transportation effect was quite low compared to raw materials production and the process of bottling like red wine. However, it was observed little difference in releasing CO_2 amount between the two wines for this step. In Fig. 5., waste management strategies of the glass and top on CO_2 amount were displayed. So, it was determined that the amount of using glass affected the CO_2 emissions during disposal at the recycling plant. As a result, the total GHGs emission amount for one bottle of white wine was found as 0.217 kg CO_2 eq./functional unit.

TABLE VII. CARBON FOOTPRINT RESULTS FOR TRANSPORTATION OF WHITE WINE

Material Transported	*Transport Type*	*CO_2 eq. (kg/f.u.)*
Glass-bottle (virgin)	40t truck	$3.13*10^{-10}$
	22t truck	$1.59*10^{-9}$
	Container ship	$1.41*10^{-11}$
Wood-pine timber	40t truck	$4.89*10^{-12}$
	22t truck	$2.50*10^{-11}$
	Container ship	$2.21*10^{-13}$
	Total:	$1.95*10^{-9}$

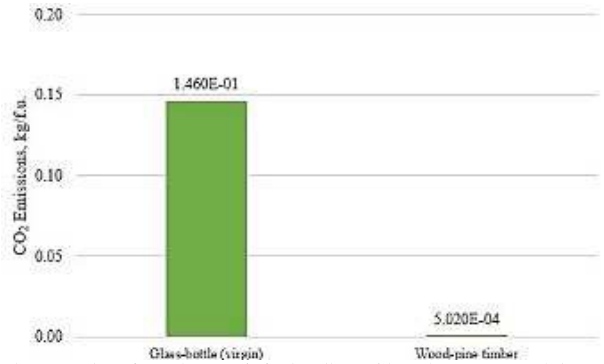

Fig. 4. Carbon footprint graph for bottling white wine raw materials

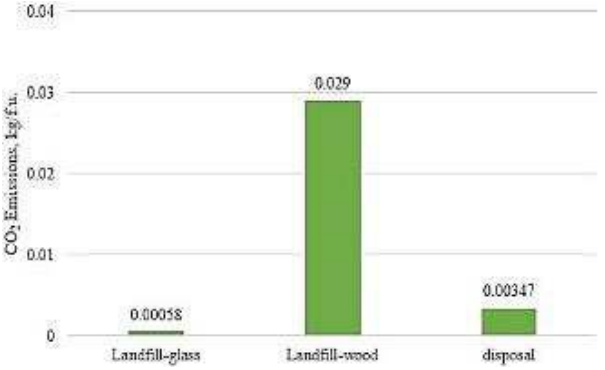

Fig. 5. Carbon footprint graph for waste management of bottling white wine raw materials

In Figure 6, it was compared white and red wine carbon footprint concerning production and disposal. It was not regarded as tiny amounts which were below 0.01 for example landfilling glasses.

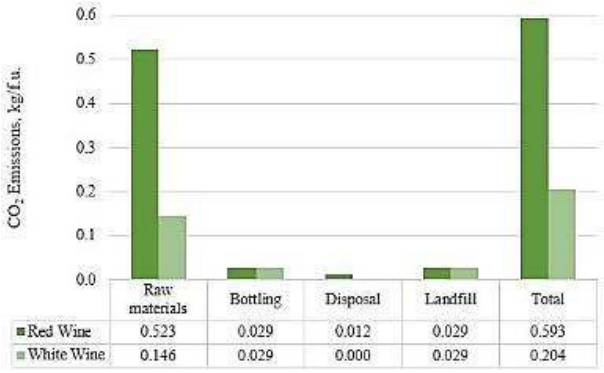

Fig. 6. Carbon footprint trends for red vs. white wine

IV. TRANSPORTATION SCENARIOS

For a one-bottle red and white wine, it can be thought transportation did not affect the CO_2 release. However, it can be important for a carbon footprint considering other scenarios. When it was assumed that the vehicles took a trip on the long way which was 1000 km for each one, the releasing CO_2 amount was high. It can be reached The results for red and white wine in Table XIII and IX respectively. When it was changed the vehicles at the same assumed distance, it was reached different results. As shown in Table X for white and Figure XI for red wine, decreasing truck weight increased CO_2 emissions. At the same time, selecting air transfer instead of sailing was effective on carbon footprint.

TABLE VIII. CARBON FOOTPRINT RESULTS FOR TRANSPORTATION OF RED WINE ON LONGER WAY

Material Transported	*Transport Type*	*CO_2 eq. (kg/f.u.)*
Glass-bottle (virgin)	40t truck	0.025
	22t truck	0.033
	Container ship	$7.61*10^{-3}$
Wood-pine timber	40t truck	$8.8*10^{-4}$
	22t truck	$1.16*10^{-3}$
	Container ship	$2.65*10^{-4}$
	Total:	0.068

TABLE IX. CARBON FOOTPRINT RESULTS FOR TRANSPORTATION OF WHITE WINE ON LONGER WAY

Material Transported	*Transport Type*	*CO_2 eq. (kg/f.u.)*
Glass-bottle (virgin)	40t truck	$7.04*10^{-3}$
	22t truck	0.009
	Container ship	$2.12*10^{-3}$
Wood-pine timber	40t truck	$8.8*10^{-4}$
	22t truck	$1.16*10^{-3}$
	Container ship	$2.65*10^{-4}$
	Total:	0.021

TABLE X. CARBON FOOTPRINT RESULTS FOR DIFFERENT TRANSPORTATION WAYS OF WHITE WINE

Material Transported	*Transport Type*	*CO_2 eq. (kg/f.u.)*
Glass-bottle (virgin)	7.5t truck	0.038
	Air cargo	0.333
Wood-pine timber	7.5t truck	$4.76*10^{-3}$
	Air cargo	0.042
	Total:	0.417

TABLE XI. CARBON FOOTPRINT RESULTS FOR DIFFERENT TRANSPORTATION WAYS OF RED WINE

Material Transported	*Transport Type*	*CO_2 eq. (kg/f.u.)*
Glass-bottle (virgin)	7.5t truck	0.136
	Air cargo	1.19
Wood-pine timber	7.5t truck	$4.76*10^{-3}$
	Air cargo	0.042
	Total:	1.37

V. CONCLUSION

Life Cycle Assessment may be used to determine the environmental impact of a product. Several tools can be used for this purpose. In this study, suitable CCaLC2 software was selected for calculations. Only carbon footprints were regarded concerning kg CO_2 eq./0.75 L wine. The effects of two types of wine (red and white) were considered on an environmental basis. Total GHG emission amounts for one bottle of red and white wine were found as 0.604 and 0.217 kg CO_2 eq./0.75 L. So, it can be said that white wine affected the environment low due to less glass being used in bottle production. This study can be enlarged to reuse recycling bottles and alternative sources of electricity. And it can be compared the effects of different packaging materials such as high and low-density polyethylene, PET, and can. In the LCA approach for wine bottling, it is important to make end-of-life studies. It has seemed that the literature is scarce on this topic. And the researchers mainly used Ecoinvent software to make their calculations [18]. So, the author did this study to show a different aspect of wine production in the literature.

REFERENCES

[1] L. Al-Ghussain, "Global warming: Review on driving forces and mitigation," Environmental Progress & Sustainable Energy, vol. 38, pp. 13-21, 2019.

[2] P. Bains, P. Psarras, J. Wilcox, "CO2 capture from the industry sector," Progress in Energy and Combustion Science, vol. 63, pp. 146-172, 2017.

[3] A.A. Marciniak, K.J. Lamb, L.P. Ozorio, C.J. Mota, M. North, "Heterogeneous catalysts for cyclic carbonate synthesis from carbon dioxide and epoxides," Current Opinion in Green and Sustainable Chemistry, vol. 26, pp. 100365, 2020.

[4] Z. Hu, Y. Wang, B.B. Shah, D. Zhao, "CO2 capture in metal–organic framework adsorbents: an engineering perspective," Advanced Sustainable Systems, vol. 3, pp. 1800080, 2019.

[5] T.K. Kanatli, N. Ayas, "Gasification of sunflower seed pulp for the synthesis of hydrogen-rich products," International Journal of Smart Grid and Clean Energy, vol. 8(2), pp. 226-230, 2019.

[6] T.K. Kanatlı, N. Ayas, "Simulating the steam reforming of sunflower meal in Aspen Plus," International Journal of Hydrogen Energy, vol. 46(57), pp. 29076-29087, 2021.

[7] A. Pandey, P. Sinha, A. Pandey, (2021). "Hydrogen production by sequential dark and photofermentation using wet biomass hydrolysate of Spirulina platensis: Response surface methodological approach," International Journal of Hydrogen Energy, vol. 46(10), pp. 7137-7146, 2021.

[8] J. Liu, Y. Li, J. Zhang, D. He, "Glycerol carbonylation with CO2 to glycerol carbonate over CeO2 catalyst and the influence of CeO2 preparation methods and reaction parameters," Applied Catalysis A: General, vol. 513, pp. 9-18, 2016.

[9] P. Roy, D. Nei, T. Orikasa, Q. Xu, H. Okadome, N. Nakamura, T. Shiina, "A review of life cycle assessment (LCA) on some food products," Journal of food engineering, vol. 90(1), pp. 1-10, 2009.

[10] C. Ferrara, G. De Feo, "Comparative life cycle assessment of alternative systems for wine packaging in Italy," Journal of Cleaner Production, vol. 259, pp. 120888, 2020.

[11] R. Iannone, S. Miranda, S. Riemma, I. De Marco, "Improving environmental performances in wine production by a life cycle assessment analysis," Journal of Cleaner Production, vol. 111, pp. 172-180, 2016.

[12] C. Ferrara, G. De Feo, G., V. Picone, "Lca of glass versus pet mineral water bottles: An italian case study," Recycling, vol.6(3), pp. 50, 2021.

[13] R. Stefanini, G. Borghesi, A. Ronzano, G. Vignali, "Plastic or glass: a new environmental assessment with a marine litter indicator for the comparison of pasteurized milk bottles," The International Journal of Life Cycle Assessment, vol. 26, pp. 767-784, 2021.

[14] R. Accorsi, L. Versari, R. Manzini, "Glass vs. plastic: life cycle assessment of extra-virgin olive oil bottles across global supply chains," Sustainability, vol. 7(3), pp. 2818-2840, 2015.

[15] T.M. Mata, C.A. Costa, "Life cycle assessment of different reuse percentages for glass beer bottles," The International Journal of Life Cycle Assessment, vol. 6, pp. 307-319, 2001.

[16] A. Aranda, I. Zabalza, S. Scarpellini, "Economic and environmental analysis of the wine bottle production in Spain by means of life cycle assessment," International journal of agricultural resources, governance and ecology, vol. 4(2), pp. 178-191, 2005.

[17] E. Bonamente, F. Scrucca, S. Rinaldi, M.C. Merico, F. Asdrubali, L. Lamastra, "Environmental impact of an Italian wine bottle: Carbon and water footprint assessment," Science of the Total Environment, vol. 560, pp. 274-283, 2016.

[18] I. Sazdovski, A. Bala, P. Fullana-i-Palmer, "Linking LCA literature with circular economy value creation: A review on beverage packaging," Science of the Total Environment, vol. 771, pp. 145322, 2021.