

The life cycle assessment (LCA) of a Chilean cabernet sauvignon wine bottle

Palabras clave: Análisis del Ciclo de Vida (ACV), vino, impacto ambiental.

Se analizó el ciclo de vida de una botella de vino cabernet sauvignon elaborada por la viña San Pedro en el valle de Curicó, Chile. El proyecto se llevó a cabo en el centro de investigación ENEA (Ente per le Nuove tecnologie, l'Energia e l'Ambiente) de Bologna, Italia, y consideró la aplicación experimental de la metodología del Análisis del Ciclo de Vida (ACV). Esta metodología permite evaluar los impactos ambientales asociados a un producto, proceso o actividad, identificando y cuantificando el consumo de materiales y energía, y las consecuentes emisiones al medio ambiente. La importancia de un análisis de este tipo radica principalmente en la evaluación detallada de los impactos y la capacidad de evaluar alternativas para reducir los daños resultantes. Los métodos de evaluación utilizados fueron Eco-Indicador 99, EPS 2000, EDIP 96 aplicados a través del software SimaPro 5.0. El análisis reflejó que durante la fase de transporte y distribución del producto se produce el mayor impacto, debido principalmente al uso del recurso combustible fósil. Como alternativa de mejora se propuso el reemplazo de la botella de vidrio por el envase tetrapack, siendo este más liviano y por lo tanto disminuyendo así el impacto del transporte. Se observó, además, la necesidad de adaptar el método de Análisis del Ciclo de Vida basándose en características y parámetros específicos para la región, ya sea Chile o Sudamérica, con el objetivo de obtener conclusiones más precisas.

Key words: Life Cycle Assessment (LCA), wine, environmental impact.

The Life Cycle Assessment of a cabernet sauvignon wine bottle produced by San Pedro winery in Chile was evaluated. The investigation was carried out by the ENEA Research Centre (Ente per le Nuove tecnologie, l'Energia e l'Ambiente) of Bologna using the experimental application of the Life Cycle Assessment (LCA) methodology. This method allows the identification, quantification and examination of the inputs and outputs of materials and energy, and the associated environmental impacts directly related to the functioning of a product or service system throughout its life cycle. The importance of this kind of analysis is the detailed evaluation of impact and the possibility to estimate alternatives in order to reduce damage. The evaluation methods used in the study were Eco-Indicator 99, EPS 2000 and EDIP 96 throughout the SimaPro 5.0 software. The analysis showed that the biggest impact was generated during the Transport and Distribution process, mainly due to fossil fuel consumption. The use of tetrapak containers instead of glass bottles was proposed as an alternative to decrease the product weight and therefore the transport impact. The need to adapt the Life Cycle Assessment to Chile or South America -based on region-specific characteristics and parameters- was suggested in order to reach more precise conclusions.

The life cycle assessment (LCA) of a Chilean cabernet sauvignon wine bottle

Marcia Montedonico

Agricultural Engineer MSc.

INTRODUCTION

During the last years there has been a continuous increase of interest on the environmental impacts of the use of products and of energy utilization. Society has become concerned about the issues of natural resources depletion and environmental degradation, and also about the impact of the products consumed. The environmental performance of products and processes has become a key issue, which is why some research centres and companies are investigating ways to minimize their effects on the environment.

Life Cycle Assessment (LCA) is a procedure used as an analytical tool for the evaluation of the environmental impact caused by a material, a manufacturing process or a product. For an end product, LCA requires both the identification and quantification of materials and energy used in all the life stages of the product, together with the environmental impact. This tool provides an adequate instrument for environmental decision support. The International Organisation for Standardisation (ISO), has standardised this framework within the series ISO 14040 on LCA.

Wine is a widely consumed product and since some decades ago those coming from the "new world" (i.e. Australia, South Africa, Chile, New Zealand, Argentina, California) are becoming more valued among European consumers. To reach this market, the bottle of wine must travel a long distance which consequently leads to environmental costs, specially related to CO₂ emissions.

The aim of the present study was to evaluate the life cycle of a cabernet sauvignon wine bottle produced by San Pedro Winery, located in the Curicó Valley, Chile. This research was conducted at ENEA (Ente per le nuove tecnologie, l'energia e l'ambiente) research centre, Bologna, Italy. For a better understanding of the investigation it is necessary to consider that all the measured factors and the evaluation methods have been developed under European parameters.

This study shows a first vision of the critical point of producing and exporting Chilean wine and pretends to be considered as an incentive to our production and consumption pattern.

LIFE CYCLE ASSESSMENT - LCA -

Life Cycle Assessment (LCA) is a tool for the systematic evaluation of the environmental aspects of a product or service system through all the stages of its life cycle, thus identifying opportunities that may improve the environmental performance.

Life cycle assessment is a “cradle-to-grave” approach for assessing industrial systems. This means that it begins with the gathering of raw materials from the earth to create the product and ends at the point when all materials are returned to the earth.

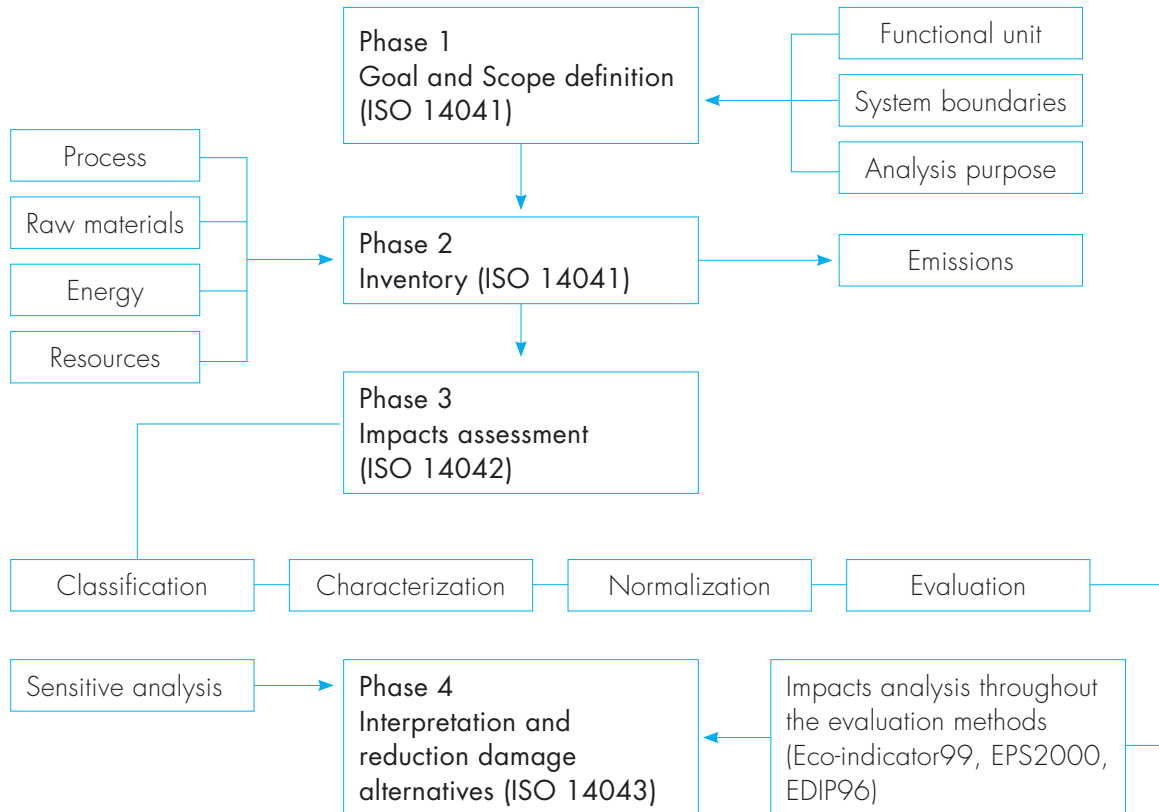
LCA enables the estimation of the cumulative environmental impacts resulting from all the stages of the product life cycle, often including impacts not considered in more traditional analyses (e.g., raw material extraction, material transportation, ultimate product disposal, etc.). By including the impacts throughout the product life cycle, LCA provides a comprehensive view of the environmental aspects of the product or process and a more accurate picture of the true environmental trade-offs in product and process selection.

Common categories of assessed damages are global warming (greenhouse gases), acidification, smog, ozone layer depletion, eutrophication, eco-toxicological and human-toxicological pollutants, habitat destruction, desertification, land use as well as depletion of minerals and fossil fuels.

The methodology is divided in four main phases:

1. Goal and Scope definition: the product(s) or service(s) to be assessed are defined, a functional basis for comparison is chosen and the required level of detail is defined (*Goal and Scope-ISO 14041*);
2. Inventory analysis of extractions and emissions: the energy and raw materials used, and emissions to the atmosphere, water and land, are quantified for each process, then combined in the process flow chart and related to the functional basis (*Life Cycle Inventory (LCI-ISO 14041)*);
3. Impact Assessment: the effects of the resource use and emissions generated are grouped and quantified into a limited number of impact categories which may then be weighted for importance. This phase involves the Classification, Characterization, Normalization and Evaluation of outcomes (*Life Cycle Impact Assessment (LCIA-ISO 14042)*);
4. Interpretation: the results are reported in the most informative possible way and the need and opportunities to reduce the impact of the product(s) or service(s) on the environment are systematically evaluated. (*Life Cycle Interpretation and improvement – ISO 14043*)

Figure 1
The LCA phases by ISO 14040 - 41 - 42 - 43



The following evaluation methods were applied in the present research:

1. ECO-INDICATOR 99: It classifies the outcomes in three categories:
 - Human Health, measured in DALY (Disability Adjusted Life Years);
 - Ecosystem Quality, in PDF*m2y (Potentially Disappeared Fraction of Plants species);
 - Resources, measured in MJ surplus
 Each damage category has different impact categories.
2. EPS 2000 (Environmental Priority Strategies in product development): contemplates four damage categories:
 - Human Health, measured in YOLL (Years Of Lost Life);
 - Ecosystem Production Capacity, expressed in Kg (unless "Soil Acidification" measured in H+ mol equivalent);
 - Abiotic Stock Resource, expressed in ELU (Environmental Load Unit);
 - Biodiversity, measured in NEX (Normalised Extinction of Species).
 Each damage category has different impact categories.
3. EDIP 96 (Environmental Design for Industrial Product): this method does not consider damage categories but only impact categories.

Moreover, the "EDIP resources only" category was applied during the evaluation, this method only estimates the damage related to natural resources (measured in kg).

SimaPro 5.0: This is the software used to assess the life cycle of the product. Based on the LCA methodology, this software is very flexible since it allows to modify the existing database (Ecoinvent) and to create new processes or materials in order to be adapted to the specific requirements of the study.

THE LIFE CYCLE ASSESSMENT OF A CABERNET SAUVIGNON WINE BOTTLED

Goal: the objective of the present study was the evaluation, throughout the application of the Eco-Indicator 99, EPS2000 and EDIP96 methods, of the environmental and human health impacts induced by the production of a cabernet sauvignon wine bottle from San Pedro Winery, on Curicó valley, Chile.

System studied: the average production of the vine is 13.000 kg/ha. One hectare was the area used to determine the various activities developed annually in the vine during the data collection.

Functional unit: a 0,75L wine bottle was the unit to which the evaluated impacts refer .

System boundary: the research comprises from the establishment of the vine until the distribution of the wine to the consumer, involving all the structure and machinery used along the different phases of the entire process.

Data quality: the Ecoinvent database from SimaPro software was employed to represent the process related transport, thermal and electric energy used. This database has been integrated with news processes from the field data collected to evaluate the materials involved in the process.

Inventory

The entire life cycle of the wine bottle was divided in six main processes, each of them containing secondary processes. The SimaPro 5.0 allows to assess independently every process as well as the general one. These processes are:

1. Vineyard establishment: tillage, structure, irrigation, planting, etc;
2. Annual cultivation: fertilization, health control, irrigation, pruning, etc.;
3. Harvest: manual and mechanical;
4. Vinification: Wine fermentation, pressing, barrels, wine treatments, etc;
5. Packaging: bottle, label, cork, cardboard boxes, etc;
6. Transport and distribution: national and for export. Based on the data provided by San Pedro Winery, 98% of the cabernet sauvignon studied was exported, mainly to the north European market (UK). Therefore the final product was shipped to approximately ten thousand kilometres.

The following table shows an example of the data introduced in the software:

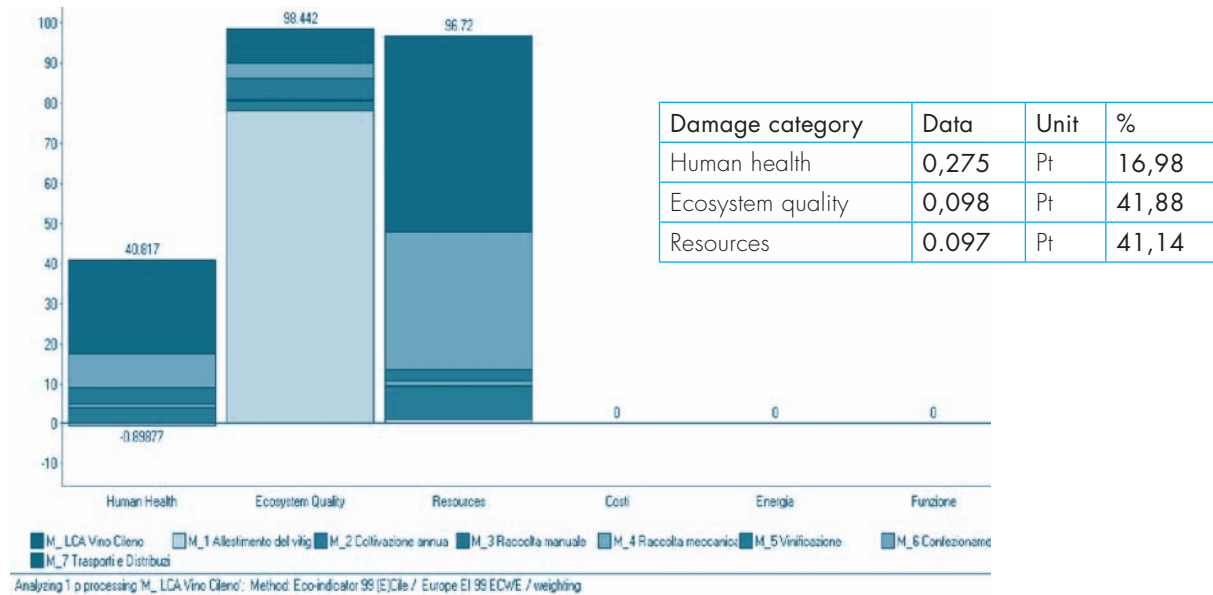
Table 1
The general LCA with the main process

LCA of a cabernet sauvignon wine of San Pedro Winery			
Process	Data	Unit	Description
LCA wine	12134	p	LCA of a Cabernet Sauvignon wine production of San Pedro winery. 1 kg grape=0,7L wine. $0,7L * 1 kg/L = 0,7kg$. $13.000kg/ha \rightarrow 0,7 * 13000 = 9100L$ 9100L/0.75L/ botella=12134 bottles. 12.134 bottles/year 2004) in 1ha.
Resources			
Stems	520	kg	Stems and pressed skins and grape seeds are spread out in the vineyard as organic material. It is the 4% of the total weight: $13000kg/4\% = 520kg$
Skins	2340	kg	It is the 18% of the total weight: $13000 * 18\% = 2340kg$
sediments	1040	kg	Dead yeasts and general sediments are the 8% of total weight: $13000 * 8\% = 1040kg$
Materials/fuels			
1 Vineyard establishment	13000	kg	Average production is 13000Kg/ha. Considering the vine life is 27 years and excluding the first two years of growth, the total production of the vine in 25 years is: $13000kg/a * 25a = 325000kg/ha$ (but all the parameters are considered for one year)
2 Annual cultivation	13000	kg	Includes all the vineyard labours: pruning, irrigation, fertilization, health control, etc.
3 Manual harvest	6500	kg	It has a low impact. The 50% of the yield is harvested in that way: $13000 * 0.5 = 6500kg$
4 Mechanical harvest	6500		The other 50% is harvested mechanically: $13000 * 50\% = 6500kg$
5 Vinification	1	p	Includes all the successive steps between the arrival of the grapes and the barrelling of the wine as well as the final treatments to stabilize the wine.
6 Packaging	1	p	Includes bottling and packaging in 12 bottles boxes.
7 Transport and Distribution	1	p	National and export transport.
Non material emission			
Function usefulness	60665	p	As the food pyramid informs, wine provides the 5% of an adult daily nutrition requirement (1 or 2 glasses): $12133 * 5 = 60665$

Eco-Indicator 99

Graphic 1

“Damage category” evaluation of the wine bottle LCA through E99 method



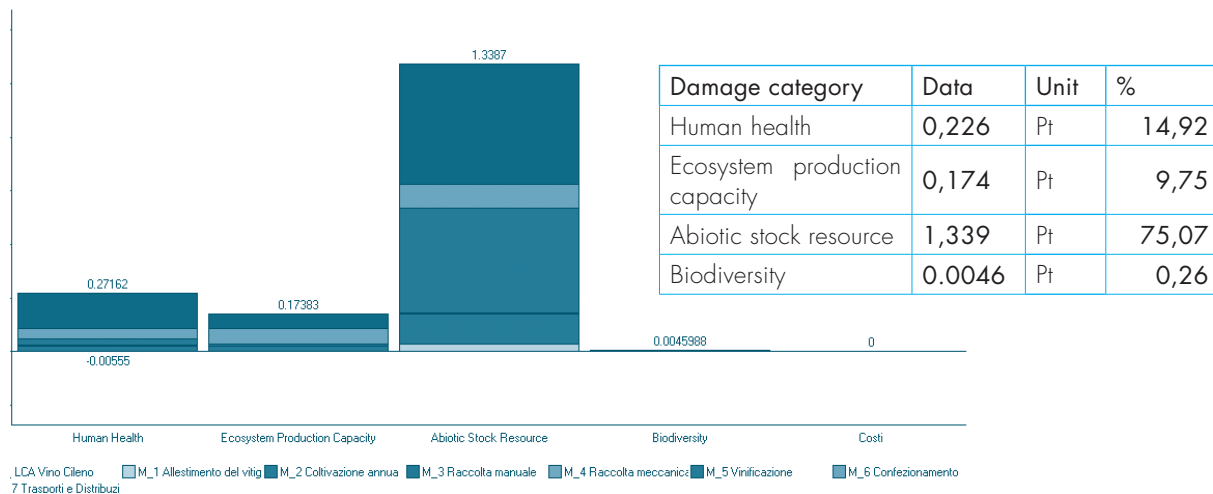
The greatest damage takes place during the Transport and distribution process (violet) mainly due to the fossil fuel use. Secondary, the Packaging process (green) causes important damage principally due to paper use. Moreover, the Vineyard establishment (yellow) evidences a big damage due to Land use impact.

The categories Resources and Ecosystem quality contain more than the 80% of the damage produced mostly due to the three processes named before.

EPS 2000

Graphic 2

“Damage category” evaluation of the wine bottle LCA through EPS2000 method



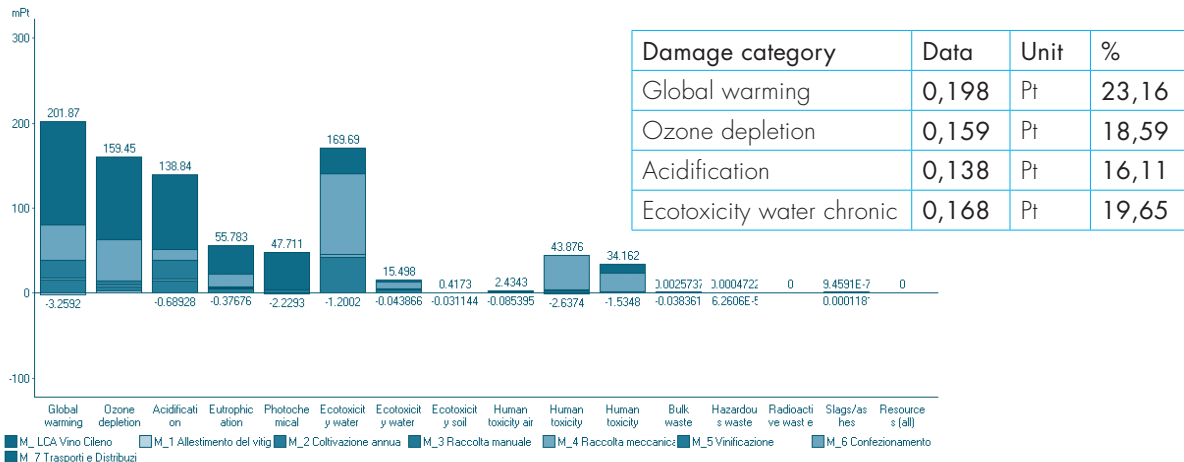
In the same way of E99, EPS 2000 shows an important damage during the Transport and distribution

(violet) process and also in the Packaging (green) process. The biggest impact is developed in the Abiotic stock resources damage category (75%) and it is mainly due to the Vinification (pink) process together with the two processes above mentioned

EDIP 96

Graphic 3

“Damage category” evaluation of the wine bottle LCA through EDIP96 method



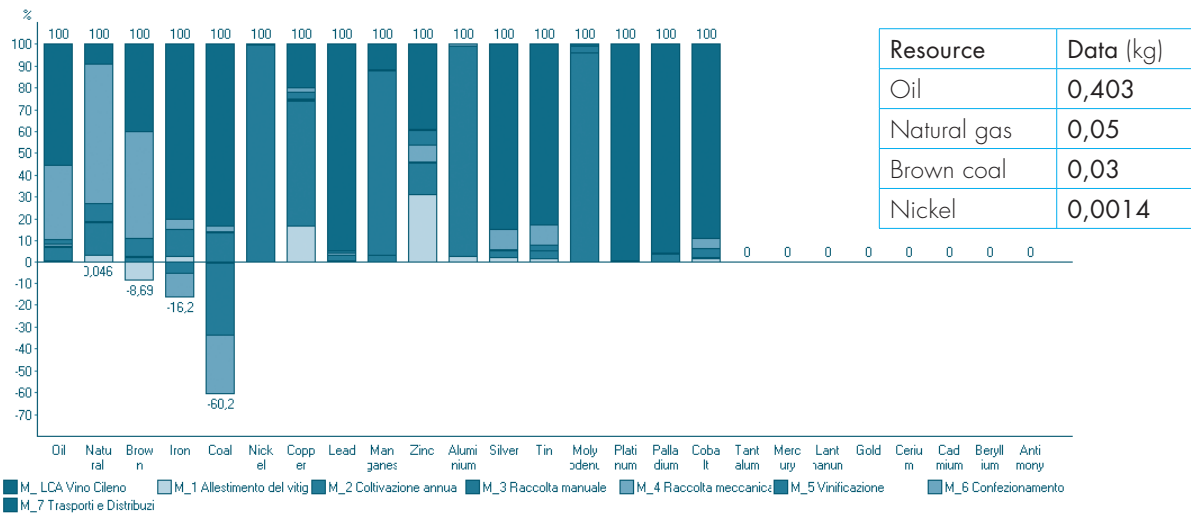
Analyzing 1 p processing 'M_LCA Vino Cileno'; Method: EDIP/UMIP 96 Cile / EDIP World/Dk / weighting

The EDIP 96 method confirms that the greatest damage occurs in the Transport and distribution process (violet) and also during the Packaging process (green). This method also shows that the biggest impact takes place in the Global warming category and secondarily in the Ozone depletion category.

EDIP resources only

Graphic 4

Characterization of the wine bottle LCA with EDIP (resources only) method



Analyzing 1 p processing 'M_LCA Vino Cileno'; Method: EDIP/UMIP 96 (resources only) Cile / EDIP World/Dk / characterization

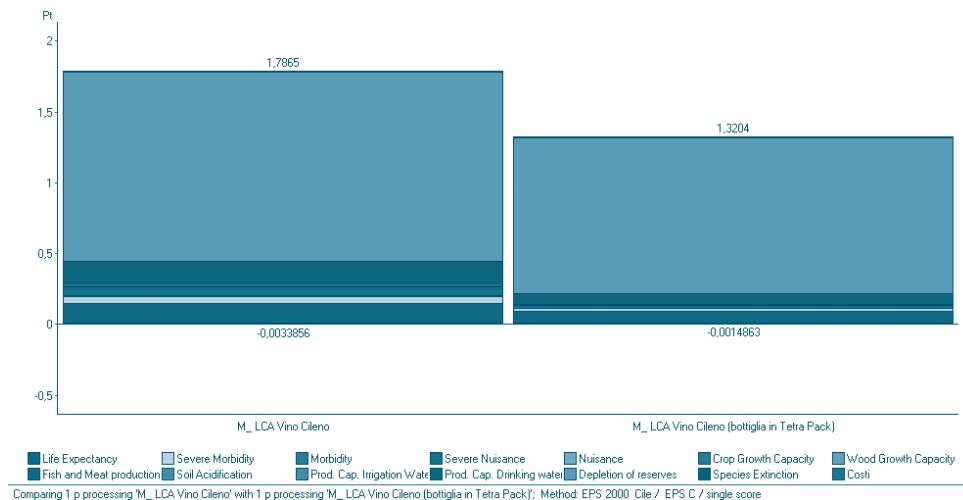
From the point of view of EDIP resources only method, the resources widely used are oil (as part of the fuel needed for transport), Natural gas, Brown coal and Nickel (used as building material of the stainless steel wine tanks containers).

SENSITIVE ANALISYS

Based on the outcomes of the analysis, the greatest damage when elaborating a bottle of wine occurs during Transport and distribution of the product. Therefore a sensitive analysis was carried out replacing the glass bottle for a tetrapack container. The last one is lighter because it is made from plastic and aluminium materials and it could decrease the fossil fuel consumption in transport since this is measured in Ton*Km.

The next figure shows the total damage reduction obtained by changing the wine container. A reduction of 0,47 points equivalent to the 26% can be observed.

Graphic 5
Comparing "LCA Wine bottled" and "LCA Wine tetrapack" with EPS2000 method



CONCLUSIONS

The greatest damage when elaborating a bottle of wine occurs during the Transport and Distribution process due to fossil fuel use. This outcome shows a global matter: the deep crisis related to the consumption and exhaustion of non renewable resources. At the same time it evidences not only the urgent need to find new energy sources, but also the importance to reflect on our predatory consumption and production patterns.

All of the three methods applied during the analysis show Packaging as a relevant damaging process, mainly due to the paper labels and the cardboard boxes employed. Unlike the other methods, Eco-Indicator 99 indicates the Vineyard establishment as a significant damaging process inside the Land use category (within Ecosystem quality). On the other hand, EPS 2000 evidences the damage produced inside the Depletion of reserves category (within Abiotic stock resource) during the Vinification process.

As an alternative to the glass bottle a tetrapack container was evaluated, with the aim to reduce the weight of the product and therefore reduce the fossil fuel required for the transport. However, this alternative would require an impact analysis on the chemical and flavour characteristics of wine and also on the consequences on the product marketing.

Since the LCA methodology was built and calibrated in Europe, during the present research the requirement to adapt the parameters to a different environmental and social context was revealed. The need to develop a more region-specific Life Cycle Assessment method with parameters based on the Chilean or South American conditions is required in order to reach more precise conclusions.

REFERENCES

- BADINO V., BALDO G.L. LCA: Istruzioni per il uso – Progetto Leonardo, p. 168, Bologna, Febbraio 1998.
- BENGT STEEN, CPM (Centre for the environmental assessment of Products and Material systems). A systematic approach to environmental priority strategies in product development (EPS). Version 2000 – General system characteristic. CPM report 1999:5, Chalmers University of Technology, 2000.
- CONAMA (Comisión Nacional del Medioambiente). Proyecto minimización de residuos de envases y embalajes - Guía metodológica Estudio de Ciclo de Vida ECV. Gobierno de Chile, Gennaio 2002.
- ENEA. Rapporto energia e ambiente. L'analisi, 2003.
- ENEA. Rapporto energia e ambiente. I dati, 2003.
- HAUSCHILD M., POTTING J. Background for spatial differentiation in life cycle impact assessment – The EDIP 2003 methodology. Institute of Product Development, 2004.
- MORELLI M., BARDASI G., CRISTOFORI D., DAL BIANCO E., SPEZZANI P. LINONI F., POLELLI M., Valutazione di impatto ambientale, (2 edizione) REDA, Roma, 1989.
- Pré (Product ecology consultants). The ECO- Indicator 99. A damage oriented method for Life Cycle Impact Assessment. Methodology Report, 2001.
- Pré (Product ecology consultants). SimaPro 5.0. reference manual, 2001
- WENZEL H., HAUSCHILD M., ALTING L. Environmental assessment of products – Vol. 1: Methodology, tools and case studies in product development. Chapman and Hall, London 1997.

