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Preliminary environmental study of the citrus industry or Tucuman (Argentina) based on the Life Cycle Assessment

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Abstract

This work presents a preliminary study of the citrus industry in Tucumán (Argentina) through the Life Cycle Assessment (LCA) methodology. The study involves a “cradle to gate” approach, in which three main products are considered: essential oil, dehydrated peel and concentrated juice. A year of harvest is considered as temporal scope, and the functional unit is represented by a reference flow of 100 tons of lemon fruit. Two allocation approaches are considered: by mass and by economic value. Results clearly show the negative impact of the agricultural activities due to synthetic agrochemicals use, which may be regarded as an interesting improvement hotspot. When mass allocation is considered, it is remarkable how dehydrated peel greatly contributes to most of the impact categories. However, the analysis considering economic allocation shows that the impact is transferred to essential oil and concentrated juice.

Keywords: lemon, essential oil, concentrated juice, dehydrated peel

Introduction

The purpose of this work is to obtain a preliminary environmental profile of the citrus industry in the province of Tucumán (Argentina) by using the Life Cycle Assessment (LCA). In spite of its relevance, it is noteworthy that there are no contributions on this subject in Argentina. There are just a few studies worldwide: two works by Becalli*et al*. (2009, 2010) and one by Pourbafrani*et al*. (2013), a carbon balance in citrus plants (Iglesias *et al*. 2013), and an economic and environmental analysis of lemons and oranges production (Pergola *et al*. 2013). In Becalli*et al*. (2010), the authors claim that their work is one of the first contributions to the LCA application on oranges, lemons, and their industrial derivatives (essential oil, and natural and concentrated juice). The same assertion can be found in Cerutti*et al*. (2014), an article addressing the state of the art on LCA studies of different fruits (e.g. pineapples, apples, oranges, lemons, strawberries).

Argentina is one of the worldwide leading lemon fruit producers. Among Argentinean provinces, Tucumán concentrates annually around 87% of the production, and 86% of the total surface area designated to the lemon cultivation, which positions Tucumán as the most important producer of this fruit (EEAOC 2014). This activity has been facing a sustained growth since 1980. Of the lemon production, 75% is industrialized in the plant of eight companies to obtain concentrated juice, essential oil and dehydrated peel among other sub products. The rest is sold as a fresh fruit, sending around 20% to the external market (Sota 2007).

Methodology

It is used a "from cradle to gate" approach, i.e. from cultivation of the raw material (lemon trees) to obtain essential oil, concentrated juice and dehydrated peel as finished products. Data used in the inventory phase are mostly data collected from, experts in the field and from a citrus company in Tucumán with which there exists a cooperation agreement.

As temporal limit, an annual harvest campaign is considered. The functional unit is translated into a reference flow of 100 tons of lemon fruits. For the impact assessment, the CML-2001 methodology is used and the case study has been implemented in Simapro® 8.0.3 (2014).

Figure 1 depicts the global system with inputs, outputs and intermediate materials.

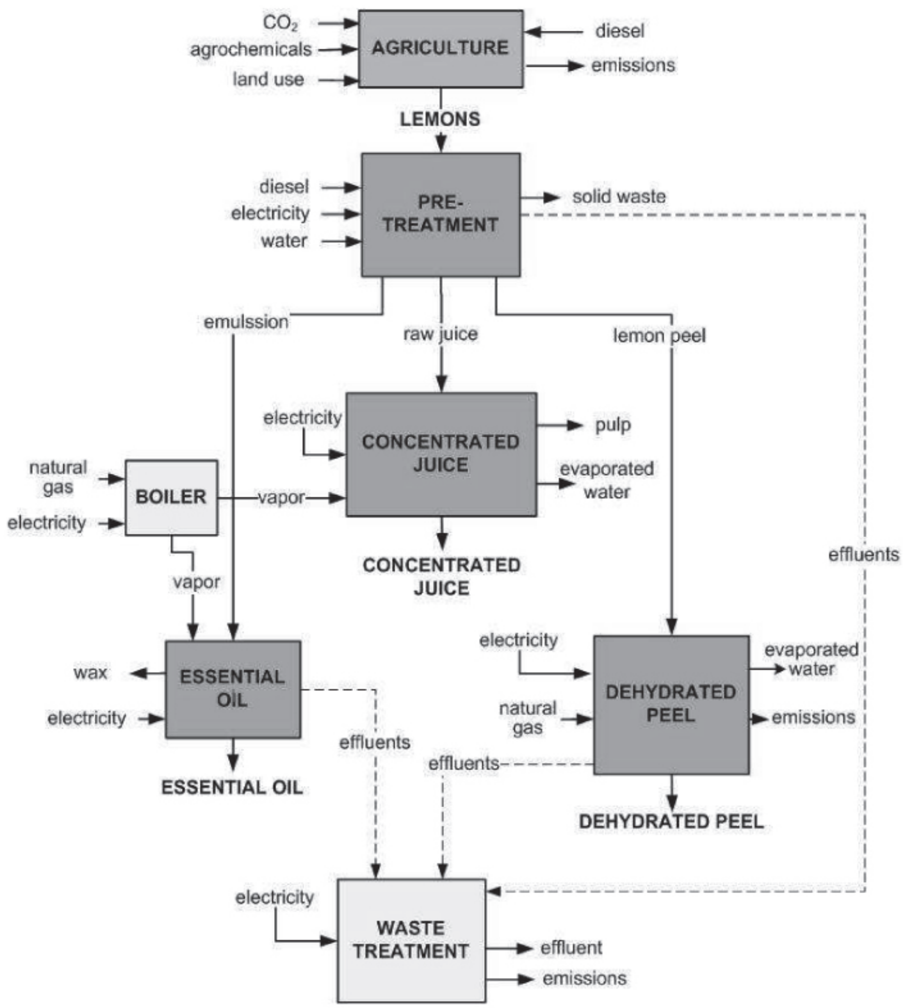

Figure 1 Schematic of the total system including seven subsystems.

This system is divided into seven subsystems, namely: *Agriculture*, *Pre-Treatment*, *LEO* (lemon essential oil), *CLJ* (concentrated lemon juice), *Dehydrated Peel*, *Boiler* and *Waste Treatment*. In the *Agriculture* subsystem, lemon is grown; fertilizers, herbicides and pesticides are supplied; then lemon is harvested and transported to *Pre-Treatment* subsystem (at the processing plant). In this subsystem, lemon is unloaded, weighted, selected and washed. Then, it is sent to a set of grater and extractor machines, where three intermediate products are obtained (emulsion, juice and peel). These products will act as raw materials of the subsystems *LEO*, *CLJ* and *Peel*. The emulsion enters the *LEO* subsystem and it is centrifuged to remove water and impurities. After that, clean essential oil is packed and stored for 25 days to complete the dewaxing process. In the *CLJ* subsystem, juice is filtered and centrifuged to separate the pulp. It is then pasteurized and concentrated, and then packaged and refrigerated. The peel coming from the extractor machines enters the *Dehydrated Peel* subsystem. There, the peel is washed, pressed and sent to the driers, yielding a product with a moisture content of 8-12%. Finally, dry peel is cooled and sent to the compactors where the product is bagged in bags. The *Waste Treatment* subsystem receives the effluents from lemon oil sector, from the screening and washing lemons (*Pre-Treatment*) and from the *Dehydrated Peel* subsystem. In the *Boiler* subsystem, generated vapor is fed to essential oil distillation and juice concentration. For each of the subsystems, inputs and outputs flows are identified and quantified (inventory phase of LCA). The case study is performed considering both mass and economic allocation, since the process of citrus has three important products (Table 1).

Product	Mass Allocation Factor	Economic Allocation Factor
LEO	0.76%	38.33%
CLJ	8.44%	40.94%
Dehydrated peel	90.79%	20.73%

Table 1 Allocation factors for mass and economic allocation approaches

As noted, the essential oil is the product obtained in smallest amounts but with greatest economic value, whereas for dry peel, the opposite occurs. For every 100 t of lemon, 44.26 kg of essential oil, 4.94 t of concentrated juice and 53.12 t of dried peel, are obtained.

Results

In Figure 2, comparative results obtained for the three main products, considering mass allocation, are shown.

In most impact categories, the product having the largest impact on the environment is the dehydrated peel, especially in abiotic depletion (AB), global warming (GW), ozone layer depletion (OD), terrestrial ecotoxicity (TE) and photochemical oxidation (PO). In acidification (AD) and eutrophication (EU), concentrated juice has the biggest impact. Concerning GW, dehydrated peel exhibits by far the largest impact.

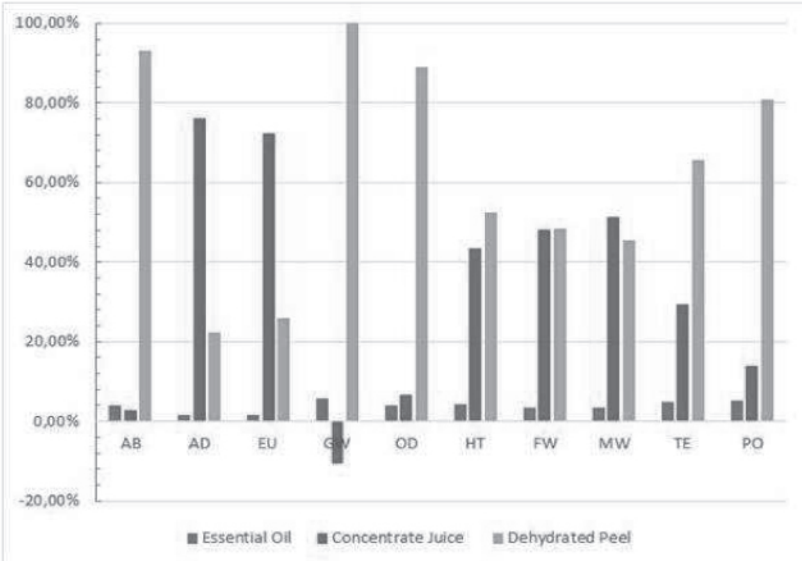

Figure 2 - Citrus industry profile by product. Mass allocation. Abiotic depletion (AB), Acidification (AD), Eutrophication (EU), Global warming (GW), Ozone layer depletion (OD), Human toxicity (HT), Fresh water aquatic ecotox. (FW), Marine aquatic ecotoxicity (MW), Terrestrial ecotoxicity (TE), Photochemical oxidation (PO).

Although smaller than in the case of dehydrated peel, the only environmental positive impact is that associated to the concentrated juice. Essential oil has a negative environmental impact in all the categories, always smaller than those corresponding to dehydrated peel. Regarding to *Agriculture* subsystem, results can be seen in Figure 3.

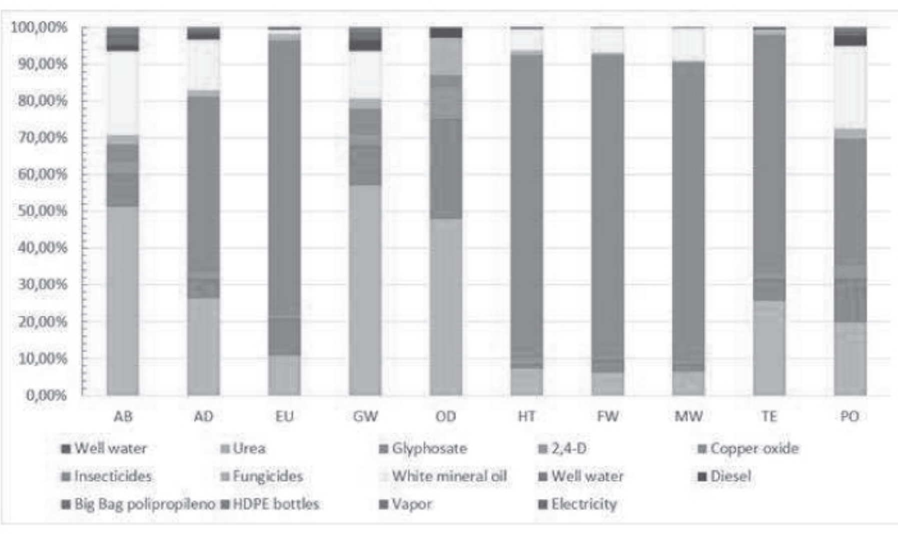

Figure 3 - Agriculture subsystem. Abiotic depletion (AB), Acidification (AD), Eutrophication (EU), Global warming (GW), Ozone layer depletion (OD), Human toxicity (HT), Fresh water aquatic ecotox. (FW), Marine aquatic ecotoxicity (MW), Terrestrial ecotoxicity (TE), Photochemical oxidation (PO).

It clearly shows the negative impact of the use of agrochemicals such as copper oxide, urea and glyphosate, in all categories. Fertilizers production, i.e. urea, and glyphosate production contribute mainly to GW. The fertilizer use causes nitrogen releases in the form of NH_3 and N_2O to the air, and nitrates to the water. LCA results considering economic allocation can be seen in Figure 4.

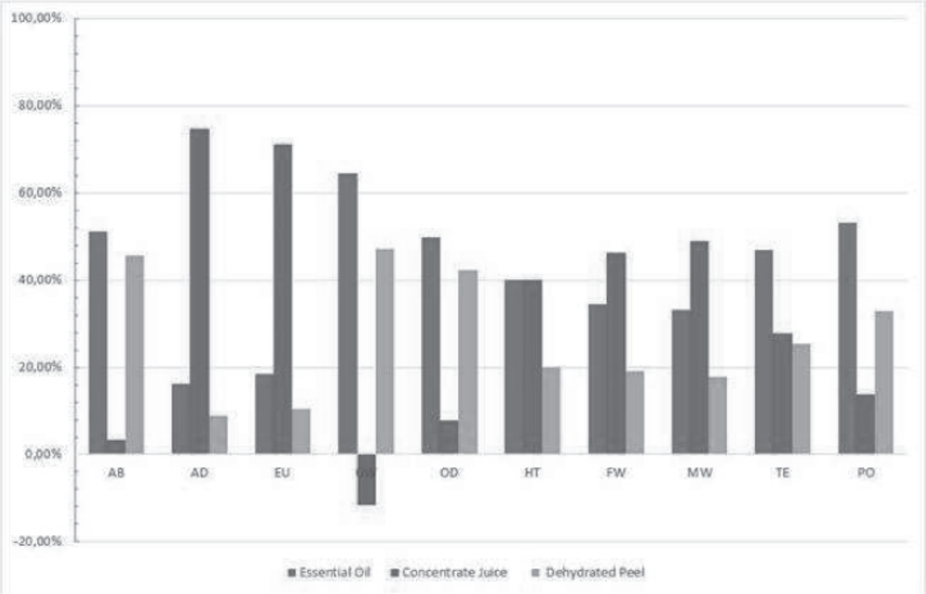

Figure 4 - Citrus industry profile by product. Economic allocation. Abiotic depletion (AB), Acidification (AD), Eutrophication (EU), Global warming (GW), Ozone layer depletion (OD), Human toxicity (HT), Fresh water aquatic ecotox. (FW), Marine aquatic ecotoxicity (MW), Terrestrial ecotoxicity (TE), Photochemical oxidation (PO).

It can be noted that the contribution of oil and juice grows with respect to the peel. The essential oil has great impact in AB, GW, OD and categories associated with toxicity, while concentrated juice prevails in AD, EU and categories related to water.

Conclusions

It is worth bearing in mind the importance of assessing the environmental profile of the value chain associated with lemon, since the Argentine Ministry of Agriculture, Livestock and Fishery has selected this fruit as a priority exportable crop in this country. This preliminary work is an important contribution because, to the best of our knowledge, LCA studies on the citrus industry are nonexistent in Argentina and scarce worldwide. Results obtained show the need to consider other agrochemicals to replace those currently used, thus reducing environmental burdens. It can be also observed the high sensitivity of the conclusions to the allocation method considered.

Some of the studies that may arise from the one presented are: sensitivity and uncertainty analysis over certain identified parameters; and use of the results on the multi-objective optimization of the lemon industry supply chain, considering at once economic, environmental and social criteria.

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References

[1] Becalli, M., Cellura, M., Iudicello, M., Mistretta, M. (2009). Resource consumption and environmental impacts of the agrofood sector: life cycle assessment of Italian citrus-based products. Environmental Management, 43, 707-724.

[2] Becalli, M., Cellura, M., Iudicello, M., Mistretta, M. (2010). Life cycle assessment of Italian citrus-based products. Sensitivity analysis and improvement scenarios. Journal ofEnvironmental Management, 91, 1415-1428.

[3] Cerutti, A., Beccaro, G., Bruun, S., Bosco, S., Donno, D., Notarnicola, B., Bounous, G. (2014). Life cycle assessment application in the fruit sector: state of art and recommendations for environmental declarations of fruit. Journal of Cleaner Production, 73, 125-135.

[4] EEAOC Agroindustrial Report. Satellite survey of crops in the province of Tucumán Nº 97, September 2014.

[5] Iglesias, D., Quiñones, A., Font, A., MartínezAlcántara, B., FornerGiner, A., Legaz, F., Primo Millo, E. Carbon balance of citrus plantations in Eastern Spain. Agriculture, Ecosystems and Environment, 171, 103-111.

[6] Pergola, M., D'Amico, M., Celano, G., Palese, A., Scuderi, A., Di Vita, G., Pappalardo, G., Inglese, P. (2013). Sustainability evaluation of Sicily's lemon and orange production: An energy, economic and environmental analysis. Journal of Environmental Management, 128, 674-682.

[7] Pourbafrani, M., McKechnie, J., MacLean, H., Saville, B. (2013). Life cycle greenhouse gas impacts of ethanol, biomethane and limonene production from citrus waste. EnvironmentalResearchLetters, 8, 015007-015018.

[8] SimaPro 8.0 PRéConsultantsbv 2014.

[9] Sota, G.A. Industria citrícola: costos conjuntos y costeo variable perfeccionado, XXX Congreso Argentino de Profesores Universitarios de Costos, Santa Fe, Argentina, 2007.