CARBON FOOTPRINT OF BEER – ANALYSIS OF A SMALL SCALE PROCESSING PLANT IN CHILE

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Abstract
This study evaluated carbon footprint of beers produced in the Region of La Araucanía (Chile) using standard PAS 2050 (2008). Four types of beer were evaluated and strategies to minimize greenhouse gas (GHG) were identified. The process steps considered were the production of malt, bottles, liquid CO2, packaging of beer, beer production, solid waste management and transportation to retail. The software SimaPro 7.3.2 was used to perform this evaluation, selecting IPCC 2007 methodology for impact evaluation. The functional unit was defined as 330 mL of bottled beer. The results indicate that the business-to-business (B2B) carbon footprint of ale, bock, lager and weizen beer have 585, 605, 572 and 593 g CO2 eq by each 330 cm3 of bottled beer respectively. The beers have a mean carbon footprint of 589 g CO2 eq, and the main source of GHG are the production of bottles (35%), transportation to retail (26%) and production of malt (17%). Considering the life cycle stages, the distribution of the carbon footprint was 53% upstream, 20% manufacturing and 27% downstream. Compared to carbon footprints stated in Environmental Product Declarations (EPD), our study estimated an approximately 10% less GHG emissions. This may be explained by the use of lower levels of mechanization and the smaller scale of production (1,500 hL/year). As an alternative to decrease the carbon footprint, this study also evaluated the impact of decreasing the weight of the bottles from 5 to 10%, which reduces the carbon footprint in up to 5% (567 g CO2 eq/bottle).

Keywords: Carbon footprint, beer, LCA

1. INTRODUCTION
The brewing industry uses malted barley, hops, water, energy and other inputs to produce, through fermentation, an alcoholic beverage. From 2004 to 2008, the Chilean beer industry grew in its production of 41.7%, allowing consumption to reach 36 L / capita in 2008. During the production process of the beers are generated solid waste, wastewater and gaseous emissions. These environmental issues can cause eutrophication, contamination of soil and groundwater, and contribute to the greenhouse effect [9]. The latter is a natural phenomenon that helps maintain a relatively constant temperature between the surface and the troposphere (IPCC, 2007), due to the presence of gases such as CO2, CH4, N2O, CFCs, PFCs and water. However, excessive anthropogenic emissions of GHG, especially CO2, [7], global temperature has increased at a rate of 0.2 to 0.3 ° C per decade [5], thus provoking global warming [6]. To reduce GHG emissions, several nations signed the Kyoto Protocol, committing their reduction. To achieve this goal some countries have created and implemented several tools to reduce greenhouse gases emitted by their organizations and potential economic benefit to them, as well as better environmental management. Among these tools is the carbon footprint [7].

2. METHODOLOGY
2.1 Objective and scope
The aim of this study was to determine the carbon footprint of products made by a brewery (hand) in the region of La Araucania. The products selected were four types of beers produced by the
organization (ale, bock, weizen and lager), which are packaged in glass bottles and marketed in the country and abroad.

The function identified in the system studied was brewing and functional unit (FU) was defined as 330 cm³ of bottled beer. The reference flow was determined as 330 cm³ to 95.2 cm³ cooked must more bottle.

The study considered the calculation of a preliminary carbon footprint to determine the limits of the system. We used the burden of GHG sources found in the life cycle of the beers, excluding all system sources that contribute less than 1% of the burden of GHG calculated from extraction of raw materials to the arrival of the product door retail (for B2B), or until it is sold (for B2C).

2.2 Inventory
The inventory analysis was performed through databases, literature, equipment manuals, information providers and on-site survey data in the brewery.

2.3 Calculation of carbon footprint
Performed inventory analysis and calculation of preliminary carbon footprint, we calculated the indicators of each beer for evaluation B2B and B2C. To calculate the carbon footprint methodology was used as the reference standard PAS 2050 [8].

2.4 Calculation of uncertainty
The uncertainty, which aims to reveal the reliability of data used and results obtained in LCA [4]. The uncertainty was through a Monte Carlo analysis using the software SimaPro 7.3.2. The calculation parameters considered measure reliability, timeliness, geography, completeness, technology and sample size.

2.5 SimaPro software and strategies to minimize GHG
To calculate the carbon footprint and simulate minimization strategies, we used the SimaPro software (version 7.3.2). To reduce GHG loads generated by sources of increased participation in the life cycle of products, the study included the identification of strategies for its minimization. Their impact on the indicators was calculated as the percentage reduction in generating carbon footprints. To identify the different minimization strategies were modeled scenarios which were sensitized through the software to check the effect of each on the mediated outcome.

3. RESULTS AND DISCUSSION
3.1. Carbon footprint
The footprint obtained in the four beers, studied using a B2B and B2C evaluation is presented in Figure 1. This indicates that the ale, bock, weizen and lager in the first evaluation, have a value of 527.9, 547.8, 514.6 and 535.8 g CO2-eq/UF respectively, and in B2C, 544.9, 564.8, 531.6 and 552.8 g CO2-eq/UF. The difference in their charges is determined by the malts, and transporting them. S and determined that more beer is the environmental load type weizen bock followed, ale and lager. S owever, according to the uncertainty of the results, this difference may be insignificant. To assess the significance of the results, Lizo area of Monte Carlo analysis, which showed (Figure 1) that there is no significant difference between the carbon footprints of beers. Moreover, the results indicate a high uncertainty in the indicators, calculated at approximately + / - 161.0 g CO2-eq. The main cause of this, the high use of inventory data from commercial databases.

Figure 2 (a) shows the contribution of CO2-eq at each stage of the life cycle of beers, this indicates that the stage of raw materials has a stake about 71.6%, 4.6% manufacturing, distribution / retail 23.3%, 0.1% consumer use and disposal / recycling 0.4%.
Figure 1: Carbon footprint and uncertainty of ale, bock, weizen and lager, evaluated in a life cycle Business-to-Business and Business-to-Consumer..

Figure 2: (a) Percentage distribution of the carbon footprint of each stage of the life cycle of beer, and (b) percentage distribution of the carbon footprint of the stage of raw materials.

Figure 2 (b) shows a percentage breakdown of the carbon footprint of the stage of raw materials. It is observed that the production of bottles is the main contributor of greenhouse gases, with a contribution of 53% in the carbon footprint, followed by Malta with 25%.

By comparing the results obtained with EPD (EPD) EPD presented in [1, 2, 3] shows that the carbon footprint reported higher values. The cause of this increase is associated with increased mechanization and technology used in the production of these beers, and its high burden in the preliminary phases of manufacturing.

Table 1 lists the quantities upstream, and downstream manufacturing footprints of the beers, the largest being in upstream GHG emissions..

<table>
<thead>
<tr>
<th>Beer</th>
<th>g CO2-eq./330 cm³ de beer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Upstream</td>
</tr>
<tr>
<td>Cerveza estudiada</td>
<td>392,9</td>
</tr>
<tr>
<td>EPD, [1]</td>
<td>433,3</td>
</tr>
<tr>
<td>EPD, [2]</td>
<td>486,8</td>
</tr>
<tr>
<td>EPD, [3]</td>
<td>449,4</td>
</tr>
</tbody>
</table>

3.2. Strategy to reduce GHG

The current production of glass bottles (green), along with transport to the brewery, have a 46% contribution to the indicators (250.9 g CO2-eq), and this can be increased by 1% if the input is changed to amber. To minimize the contribution of GHG was evaluated bottles reduce the weight of
these in 5% and 10%. This can be achieved reductions of 12.1 and 25.1 g-equivalent CO2 respectively (Figure 3), which allows to reduce about 2% and 5%, of the footprint of products.

**Figure 3:** Effect of transport and production of various types of bottles

4. **CONCLUSIONS**

It was determined that the carbon footprint study had a low carbon footprint compared to some values reported in EPD of beers. However, the results show a high uncertainty of about +/- 161 g/cm³ CO2-equivalent/330 cm³ of beer. This is mainly due to the large amount of data foreign databases used in relation to data in the foreground. In this sense, the development of inventories of national life cycle would reduce the uncertainty of national studies.

5. **REFERENCES**