Environmental performance of laying poultry in an intensive and automated system in Southern Brazil

Análise ambiental da avicultura de postura em sistema intensivo e automatizado no sul do Brasil

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ABSTRACT

Eggs are an animal protein of high nutritional value and is considered an alternative source to red meat. It is accessible to all social extracts. In addition, substantial demand growth is expected in the coming decades, which requires a significant increase in production volume. Consequently, there is a question of how these eggs will be produced. The current production systems must meet demands related to environmental sustainability, ensuring food security in terms of production volume and product safety. Thus, this study assesses the environmental performance of intensive and automated egg production in conventional cages in the southern region of Brazil. The data that comprise the inventory were modeled from data collected on a farm between 2017 and 2018. We conducted the assessment using the methodology of life cycle analysis (LCA) and the software Open LCA v. 1.7.4. The functional unit (FU) used was one ton of eggs (equivalent to 17,873 units), and the results were allocated financially. The impact attribution method was CML 2002; the database was Ecoinvent v. 3.4. The impact categories evaluated were acidification, with a total impact of 6.47 kg SO₂-eq/FU, eutrophication, with a result of 4.17 kg PO₄-eq/FU, and a carbon footprint of 1,411.85 CO₂-eq/FU. We conclude that the environmental externalities of egg production in Brazil’s southern region are similar to those reported by other studies worldwide. The production phase is responsible for about 85% of the environmental impacts in the categories evaluated. The feeding of birds contributes to the largest share of impacts.

Keywords: Egg industry; Environmental performance; Sustainability; Layers
RESUMO

Ovos são uma proteína animal de alto valor nutritivo e considerada uma fonte alternativa à carne vermelha e acessível a todos os extratos sociais. A demanda por ovos no mundo até 2050 deverá crescer em 303%. Para atendê-la será necessário o incremento significativo no volume de produção, e que leva ao questionamento de como estes ovos serão produzidos. Os sistemas produtivos atuais deverão atender questões relativas a sustentabilidade ambiental e garantir a segurança alimentar tanto em volume de produção como em inocuidade do produto. Este estudo realizou a avaliação do desempenho ambiental da produção intensiva e automatizada de ovos em gaiolas convencionais, no sul do Brasil, os dados que compõem o inventário foram obtidos a partir de uma unidade produtora da região, de bibliografia e base de dados globais. A avaliação foi realizada utilizando a metodologia da análise de ciclo de vida (ACV), através do software Open LCA 1.7.4. A unidade funcional (UF) empregada foi 1 tonelada de ovos (equivalente a 17873 unidades) e a os resultados alocados financeiramente. As categorias de impacto avaliadas foram acidificação com impacto total de 6,47 kg SO2-eq/UF, eutrofização com resultado de 4,17 kg PO4-eq/UF e pegada de carbono de 1411,85 CO2-eq./UF. O método de atribuição de impacto utilizado foi CML 2002, o banco de dados usado foi EcoInvent v 3.4. Concluiu-se que a produção de ovos na região sul do Brasil é similar a outros lugares do mundo, onde a fase de produção é responsável por cerca de 85% dos impactos ambientais nas categorias avaliadas, apontando a alimentação das aves com a maior parcela de contribuição nos resultados do estudo.

Palavras-chave: Indústria do ovo; Desempenho ambiental; Sustentabilidade; Poeleiras

INTRODUÇÃO

The production and distribution of food are fundamental to human well-being. Satisfying the nutritional needs for maintaining people's lives, food participates decisively in global trade and economy and can be considered a factor of identity and social integration. Food production is conditioned to meet food security issues in terms of supply and safety. In parallel, it is also expected to include environmental sustainability (PELLETIER et al., 2018). The main challenge concerns meeting the food needs of a growing population and reducing the environmental impacts of agricultural production (FOLEY et al., 2011).

However, laying poultry presents its challenges as a food production and distribution system. According to FAO projections, the demand for eggs will grow 303% between 2010 and 2050, raising the question of how these eggs will be produced and which systems will be more efficient from an environmental point of view (FAO, 2017). This production increase has been observed for some time, mainly regarding meeting the demand for the product after proving its nutritional value and removing the dietary restriction imposed in 1968 by several countries (MCNAMARA, 2015).

To meet the growth in demand, world egg production increased by approximately 48.06% between 1999 and 2016, while in Brazil, production growth was about 56.06% in that same period (FAOSTAT, 2018). This growth was made possible by technological innovations that led to productivity gains in the egg industry. The
innovations were mainly related to birds' genetic improvement, production processes automation, egg collection, manure removal, feeding, lighting, and ventilation, among others (PELLETIER et al., 2018, CRONEY et al., 2018, DELGADO; PIACANTE; SALLA, 2017).

In addition, sustainable production requires consideration of product impacts in at least three areas: environmental, social, and economic (FLORINDO et al., 2020). The environmental performance of laying poultry has been the subject of studies in different countries and areas of knowledge. The objective is to reconcile food security with the reduction of damages to the environment and the societies directly or indirectly involved in its production (PELLETIER; IBARBURU; XIN, 2013, LEINONEN et al., 2012, LOWRANCE; HENDRIX; ODUM, 1986).

The assessment of environmental sustainability of commercial egg production presents favorable results when conducted intensively, according to several studies conducted worldwide. However, the results of these studies are related to the location, and the way production occurs and cannot be extrapolated or generalized. There is then a need to conduct regional studies of environmental impacts (ABÍN et al., 2018, PELLETIER, 2018, PELLETIER, 2017, SMITH; WILLIAMS; PEARCE, 2015, PELLETIER; IBARBURU; XIN, 2014 and PRUDÊNCIO DA SILVA et al., 2014).

Different methodologies have been used to assess the sustainability of productive systems, including life cycle assessment (LCA), seeking to identify the environmental impacts of a product or a process at each stage of its life cycle (GRAEDEL; LIFSET, 2015). The use of LCA and its applicability spread from its standardization by the International Organization for Standardization (ISO) because it is a methodology with scientific rigor and easy to understand by the general public (PATTERSON; MCDONALD; HARDY, 2017). The fact that its general principles of application are standardized (ISO 14040) has made this method the most used for assessing the impacts of production chains in the agricultural sector (SMITH; WILLIAMS; PEARCE, 2015).

In this context, using a defined and standardized methodology, it is possible to evaluate environmental sustainability in a reliable and verifiable way, and the information thus obtained can be used as a basis for decision-making on the form of production, the geographic location of facilities, and even the size of investment on a new plant or production unit (WOLF; ALLEN, 1995).

Thus, the objective of this study is to evaluate the environmental impacts resulting from the production cycle of a batch of laying birds reared in an intensive and automated
production system on a farm in the state of Rio Grande do Sul, in the southern region of Brazil.

METHODS

This research uses the LCA methodology to evaluate the environmental performance of a commercial laying farm using the intensive and automated farming system for laying hens in southern Brazil. The data of the evaluated system were collected on a farm with a capacity for up to 150,000 housed birds. It is at 29°32'17” W and 51°04'51” W in the municipality of Morro Reuter, Rio Grande do Sul, Brazil. The region's climate is Cfa - subtropical, with hot summers (CLIMA, 2018). The maximum altitude in the region is 700 meters, the average temperature is 17.5°C, and the annual average rainfall is 1,728 mm (CLIMATE-DATA.ORG, 2018).

The data are from a batch reared in an automated system whose production cycle was already finished at the time of data collection. The two warehouses (recreation and production) have a built area of 1,575 m² and are composed of four battery cages with four levels of height (vertical system). Directly below each level of cages are the manure collection mats, which carry the manure to the bottom of the house and from there out of the laying house. The egg collecting mats are arranged on each level of the cages. They move opposite to the manure mats and take the collected eggs to the front of the shed. The eggs are collected on a larger conveyor and then taken to the egg sorting room. The environmental comfort of birds during their breeding and production is provided by natural ventilation (curtains) and fans without humidification. In addition, the sheds are covered with isothermal tiles, which ensures thermal insulation on days of high temperature. The breeding shed has a heating system for the chicks through a wood furnace.

The laying hens of the studied batch were of the Novogen White lineage. In late rearing, 51,547 chicks with one day of life were housed on the farm on November 10, 2016, and transferred to the production shed on February 13, 2017, with 95 days of life and a mortality rate of 2.64%. The productive period of the batch was from February 13, 2017, to July 26, 2018, having been discarded at 88 weeks of age. Thus, the batch remained 13 weeks in the late rear and 75 weeks in production.

The birds were bred following nutritional guidelines, management, and lighting determined for the lineage to achieve the maximum possible productive performance. The birds were beak trimmed at seven days and seventy days. Table 1 describes the
formulation of feed at the different stages of rearing from the receipt of the batch to 95 days of life. After the end of the rearing phase, the birds were transported to the production shed, and the feed for the production phase was supplied. Table 2 shows its composition.

Table 1 - Composition of the feed used in the rearing phase of commercial laying birds in an intensified and automated system in Rio Grande do Sul, Brazil

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Initial (up to 40 days) %</th>
<th>Growth (41 to 80 days) %</th>
<th>Maturity (91 to 95 days) %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>61.41</td>
<td>62.50</td>
<td>58.30</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>31.70</td>
<td>16.20</td>
<td>10.20</td>
</tr>
<tr>
<td>Limestone</td>
<td>0.60</td>
<td>5.00</td>
<td>1.30</td>
</tr>
<tr>
<td>Meat and bone meal</td>
<td>4.00</td>
<td>6.00</td>
<td>5.30</td>
</tr>
<tr>
<td>Mineral supplement</td>
<td>0.40</td>
<td>0.90</td>
<td>0.15</td>
</tr>
<tr>
<td>Lysine</td>
<td>0.20</td>
<td>0.35</td>
<td>0.01</td>
</tr>
<tr>
<td>Enzyme complex</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Soy oil</td>
<td>1.10</td>
<td>0.40</td>
<td>0.35</td>
</tr>
<tr>
<td>Salt</td>
<td>0.38</td>
<td>0.15</td>
<td>5.00</td>
</tr>
<tr>
<td>Additions</td>
<td>0.20</td>
<td>8.50</td>
<td>0.40</td>
</tr>
</tbody>
</table>

Source: Data collected on the farm.

Table 2 - Composition of the feed used in the egg production phase of commercial laying birds in an intensified and automated system in Rio Grande do Sul, Brazil

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Composition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>64.600</td>
</tr>
<tr>
<td>Canola bran</td>
<td>7.000</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>13.700</td>
</tr>
<tr>
<td>Meat and bone meal</td>
<td>2.600</td>
</tr>
<tr>
<td>Thin and thick limestone</td>
<td>11.300</td>
</tr>
<tr>
<td>Methionine</td>
<td>0.050</td>
</tr>
<tr>
<td>Ground salt</td>
<td>0.320</td>
</tr>
<tr>
<td>Mineral premix</td>
<td>0.100</td>
</tr>
<tr>
<td>Choline chloride</td>
<td>0.050</td>
</tr>
<tr>
<td>Enzyme complex</td>
<td>0.005</td>
</tr>
</tbody>
</table>

Source: Data collected on the farm.

The evaluated system covered from the arrival of chicks in the late rearing until the collection of eggs and sending for classification. The egg classification process was not considered. Equipment, buildings, medications, cleaning products, and water are
outside the scope of this study. The functional unit (FU) adopted was 1,000 kg of eggs (15,873 eggs), and the evaluated batch is equivalent to 1,407.72 functional units.

Table 3 shows the inventory data of the evaluated system. For inventory analysis, some considerations are important and listed below:

i. The feed ingredients considered in the calculations participated with at least 5% in one of the formulations used throughout the total production cycle.

ii. In the transportation of feed inputs, only one route was considered, as it is an outsourced transport, and the usual is that the trucks carry a return cargo.

iii. The transport of chicks was in an air-conditioned trunk truck, with two round trips due to the number of birds transported.

iv. The transport of discarded birds requires an appropriate vehicle; in addition, health issues prevent sharing transport. In this study, two routes were considered. There were also two means of transport for manure.

v. The manure was removed, on average, once a week, and dead birds were destined for composting.

vi. The water used for hydration and handling of birds was not considered in the calculations of environmental impacts. Its exclusion is justified by the inaccuracy of the data obtained and the small contribution to the environmental effects, according to Abín et al. (2018) and Pelletier (2017).

vii. The batch was discarded at 88 weeks, and the birds were destined for slaughter in a refrigerator. The meat was destined for industrialization for human consumption.

Table 3 - Inventory data of the egg production phase of commercial laying birds in an intensified and automated system in Rio Grande do Sul, Brazil

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
<th>Late rearing</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limestone</td>
<td>ton.</td>
<td>2.11</td>
<td>192.07</td>
</tr>
<tr>
<td>Electricity</td>
<td>kWh</td>
<td>13,711.00</td>
<td>73,762.50</td>
</tr>
<tr>
<td>Canola bran</td>
<td>ton.</td>
<td>6.20</td>
<td>118.98</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>ton.</td>
<td>55.68</td>
<td>232.86</td>
</tr>
<tr>
<td>Wheat bran</td>
<td>ton.</td>
<td>17.05</td>
<td>0.00</td>
</tr>
<tr>
<td>Meat and bone meal</td>
<td>ton.</td>
<td>11.97</td>
<td>44.19</td>
</tr>
<tr>
<td>Firewood</td>
<td>ton.</td>
<td>6.25</td>
<td>0.00</td>
</tr>
<tr>
<td>Corn</td>
<td>ton.</td>
<td>151.04</td>
<td>1,098.01</td>
</tr>
</tbody>
</table>
The impacts were assigned using the software Open LCA v. 1.7.4 and the CML 2002 midpoint impact assessment method. The selection of a midpoint method is justified by assessing the direct and immediate impacts of the production system. Its use is adequate, as it is an impact-oriented approach directly related to the productive activity (CRESPO MENDES; BUENO; OMETTO, 2013). The database used was the Ecoinvent v. 3.4. The potential for eutrophication, the potential for acidification, and the potential for climate change for a horizon of 100 years were the environmental impacts categories evaluated in this analysis.

RESULTS

The products originated in the production process, and commercialized were eggs, manure, and birds discarded at the end of the production cycle. The allocation of impacts by category was calculated based on the results of impact attribution. There were four processes for impact assessment to identify which steps would most impact the environment: rearing, egg production, rearing manure, and production manure. From this, the results were allocated according to their percentage participation in the financial result obtained and related to FU (one ton of eggs). The financial allocation was obtained by the ratio between the unit value of each product and the total earned with the batch. The unit value was determined by dividing the total produced by the marketed value (Figure 1).
The financial allocation indicated that 94.4% of the impacts were from the eggs traded since this is the farm's main activity, and most of the financial return comes from it. In the following items, we detail each impact category as to the contribution of each stage of the production process and the items that contributed most to the result.

The assigned acidification was 6.85 kg SO$_2$-eq to produce one functional unit. The rearing and egg production activities were the most impactful for this impact category. The use of corn in poultry feed, both rearing and production, was responsible for 31.63% and 34.26% of acidification, respectively, being the main isolated impact factor in this category. However, crops used as inputs for poultry feed vary widely in terms of the use of natural resources and emissions attributed to them. Grasses such as corn are demanding in terms of nitrogen fertilization. In contrast, leguminous plants such as soy fix nitrogen in the soil, which tend to cause less environmental impacts regarding the use of nitrogen fertilizers (PELLETIER, N., 2017).

Manure from the rearing and production phases, proportionally, had reduced participation in the total acidification of the evaluated system (0.34%). For both types of manure, road transport was the item that most contributed to the result, totaling 15.7% for each product. The other variables are indirect and fractionated due to the impact attribution process based on data obtained from Ecoinvent.

The total eutrophication was 4.17 kg PO$_4$-eq per functional unit, with egg production and late rearing processes contributing the most to this impact category. In addition, the inputs for the feed composition contributed the largest share to this result. In the late rearing, 38.50% of the impacts attributed were related to the use of corn and
20.58% to the use of soy. In the production phase, corn accounted for 40.41% and soybean for 7.35% of impacts. This result can be justified by the fact that they are the inputs with the highest percentage in the composition of poultry feed, totaling 1,250 tons, which is higher than soybean meal, which added up to 288 tons. In addition, in the initial rearing phase, the feed is composed of about 32% of soybeans, which is reduced proportionally over time, reaching the production phase at 13.7%. The results referring to the manure from the rearing added to the production indicate the lowest participation in this impact category (0.12%). In comparison, the treatment of mining waste emerged as the largest single contributor in these two stages of production: about 24% impacts in each of the processes. This is a secondary input attributed to the database.

As in the previous categories, the production phase was also the main contributor to greenhouse gas (GHG) emissions, which is justified mainly by the period during which the birds remained in each phase: five times higher compared to late rearing. The change in land use from clearing primary and secondary forests for grain cultivation was the main contributor to this impact category, contributing approximately 34.24% of total emissions in the growing phase and 26.25% in the production phase.

Table 4 - Environmental impacts attributed per category after financial allocation

<table>
<thead>
<tr>
<th>Impact category</th>
<th>Eggs</th>
<th>Manure*</th>
<th>Discard birds</th>
<th>Total impact</th>
<th>Impact attributed per FU.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acidification (kg SO₂·eq)</td>
<td>9,104.22</td>
<td>94.42%</td>
<td>439.52</td>
<td>98.24</td>
<td>6.85</td>
</tr>
<tr>
<td>Eutrophication (kg PO₄·eq)</td>
<td>5,538.8</td>
<td>94.42%</td>
<td>267.39</td>
<td>59.77</td>
<td>4.17</td>
</tr>
<tr>
<td>Carbon Footprint (Kg CO₂·eq)</td>
<td>1,876,640.25</td>
<td>94.42%</td>
<td>90,597.32</td>
<td>20,249.80</td>
<td>1,411.85</td>
</tr>
</tbody>
</table>

*Manure refers to the sum of the aggregated values of the late rearing and produced manure.

DISCUSSION

The results of this study, in general, follow the same behavior of similar studies, which have also pointed out that the inputs used in animal feeding, such as soybeans and corn, and management and transportation of manure are the main sources of impacts caused by commercial egg production. However, a direct comparison between LCA studies on agricultural systems should be performed with caution since specific characteristics of each evaluated system and even the scope breadth can directly affect the results (FLORINDO et al., 2020).

In the present study, we opted to use the financial allocation method to distribute the environmental impacts of generated byproducts, since the egg has greater financial
representativeness compared to other byproducts. This approach is similar to that adopted by Florindo et al. (2018), who used the financial allocation method to attribute environmental impacts to beef production. However, the application of financial allocation to laying poultry varies, such as in the study of DEKKER et al. (2011), who considered manure of no economic value, differently from the case of this study, where manure has commercial value and contributes to the system's gross revenue.

Researchers like Leinonen (2012), Pelletier; Ibaruru; Xin (2014), and Abín (2018) converge in their conclusions and attribute the greatest impacts on the environment to the variables of food and manure management. Regarding manure management, the present study differed from similar ones by presenting results of acidification and eutrophication of 0.34% and 0.12%, respectively. In similar studies, this value is around 45% of the total of each of these categories (PELLETIER, N., 2017). This result can be justified by the method chosen for inventory analysis (midpoint), which assesses the effects at a midpoint where impact occurs. Similar studies have evaluated human ecotoxicity, for example, an impact not contemplated in the methodology we chose for this study.

Furthermore, this divergence in the results can also be caused by the purpose of use and the manure management method itself. According to Pelletier (2017), after poultry feed composition and feed conversion efficiency, poultry manure management is critical in egg production emissions. In addition, the composition of the feed and feed conversion of animals directly affect the emissions attributed to manure. In the case of this study, manure is sold without prior treatment (fresh) directly to farmers to be used as fertilizers, which is beyond the scope of this study.

Poultry manure is a fertilizer with a high content of nitrogen and available phosphorus, and its use in crops allows the reduction in chemical fertilizer dependence. The better its distribution and the less exposed to the environment, the better its efficiency in the use of nitrogen, with lower nitrous oxide emissions and less need for mineral fertilizers (GHASEMPOUR; AHMADI, 2016). It is important to highlight that for a broader assessment, it would be necessary to adopt a consequential approach. Part of the reduction of the environmental impact of other crops, through the use of manure, should be deducted from the initial accounting since agricultural products such as corn and soy are considered inputs to the evaluated system.

From the point of view of the life cycle assessment, the recovery of waste represents a win-win situation: it improves the use efficiency of environmental resources and the profitability of egg producers. In the present study, the disposal birds were
slaughtered, processed, and destined for human consumption, which is a good example of reusing resources and reducing environmental impacts. The use of renewable energies in egg production systems can also offer significant opportunities to improve the environmental performance of commercial egg production, an aspect that has not been considered in the system evaluated in this study. Issues related to construction technologies and equipment are also significant in improving the environmental performance of systems. An example is the use of isothermal tiles in the cover of the sheds evaluated, improving environmental comfort and reducing the need for mechanical ventilation (PELLETIER et al., 2018).

CONCLUSIONS

This study presents the life cycle assessment results of a commercial egg production unit using an intensive and automated system in southern Brazil. Its environmental performance is an essential factor to drive growth and development. It presents quantitative data on this performance, obtained through a scientific and standardized methodology.

For the impact categories evaluated (acidification, eutrophication, and carbon footprint), about 85% of the impacts generated occur at the egg production stage, and in all the evaluated categories, the grain production used in the formulation of feed, mainly corn and soybeans, is the variable with the greatest contribution to this result. Furthermore, the environmental performance of the egg production system evaluated in this study was similar to that of other similar studies conducted in Canada, Iran, and the United Kingdom.

Environmental performance can still be improved through better use of waste from this process and the use of renewable energies such as wind and solar energy. However, the mentioned absence of regional data indicates the need for further academic research aiming to draw a picture of the Brazilian reality, making evaluations increasingly regionalized by considering the local productive reality. Thus, further research on the egg production chain will increase the efficiency in the use of resources and improve the environmental performance of egg production, which is a protein of high nutritional value and accessible to most people in different social strata.

REFERÊNCIAS

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