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Life Cycle Analysis of Farmed Shrimp of the Species Litopenaeus Vannamei in the Province of Guayas

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Abstract

The main objective of this study is to quantify the environmental performance of the Litopenaus Vannamei shrimp, defining the limits of the "Cradle to the door", as a functional unit 1 kg of packed frozen shrimp was established, through the application of the Life Cycle Analysis methodology, which allows to identify the most relevant environmental aspects of the production system in the province of Guayas.

The inventory analysis was carried out through the quantification of inputs and outputs in the shrimp processing stages, whose data were processed using the Open LCA software. Among the categories of impacts to be studied are Climate Change, freshwater eutrophication and terrestrial acidification.

The results indicate that the main stages responsible for the impact are shrimp farming with a contribution of 58.26%, while the production of feed for shrimp feed on the farm represents 80.01% of CO2 emissions, which are mostly associated with the consumption of feed and fossil fuels.

Among the improvement alternatives to mitigate the environmental impact during shrimp production is the reformulation of the composition of the balance, optimization of the consumption of balancing through automatic feeders and the implementation of renewable energy systems for water pumping.

Keywords: *Life Cycle Analysis, Acidification Potential, Carbon Dioxide, Methane, Life Cycle Impact Assessment, Eutrophication Potential, Climate Change, Life Cycle Inventory.*

1. INTRODUCTION

"Aquaculture and especially shrimp farming have been great sources of employment and generators of foreign exchange for the country" (FAO, 2021).

According to National Fisheries Institute (2021) "in Ecuador, aquaculture activity has been developed based on the cultivation of white shrimp (Litopenaeus vannamei), being the coastal region where the largest aquaculture production of shrimp is concentrated at the national level"; This species is characterized by its high tolerance to physicochemical variations of water in the culture medium.

Within the export area, shrimp was one of the main non-oil products of great interest, being exported mainly to the markets of the United States, Central Europe and Asia;

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representing high income at the economic level (Chipantiza & Castillo, 2015). According to Reyes (2019), cited by Jumps (2020), the shrimp sector contributed 1.14% of the value of the National GDP during the period 2013-2017, in terms of job creation, 64% comes from activities of exploitation of hatcheries and laboratories, contributing 1.3% to employment positions at the national level.

Since the shrimp sector represents one of the most intensive activities, it requires large extensions of land, drastically transforming the area where shrimp farming takes place, which will be treated and adequate, in order to guarantee the optimal environment for the growth of larvae (López & Torres, 2020).

Borunda (2012), indicates that "the environmental impact of a product begins with the extraction of raw materials and ends when the useful life of the product ends, becoming a waste".

The Life Cycle Analysis allows to study the environmental aspects and possible impacts within the life cycle of the shrimp, considering the process that is carried out from the beginning, taking into account the raw material until the last stage of final disposal, it is also important to characterize the transportation, preparation, manufacturing, transportation to markets and other aspects within the phases that the product development fulfills (Anton, 2004).

In this study, the stages and activities of the shrimp production chain will be analyzed, adopting a life cycle approach from the "cradle to the door" identifying the environmental impact generated by these processes.

2. METHODOLOGY

The methodology for life cycle assessment is considered as a significant and quantitative method that measures environmental impact, being efficient its use in environmental management in the face of problems that arise in the environment (Meneses et al., 2016).

During the objective and scope definition phase, the functional unit is established that describes the main function of the analyzed system, in addition to providing a reference regarding the inputs and outputs of the process that can be normalized; Due to the magnitude, limits must be established to determine which unit processes should be included (Anton, 2004), during the process of the shrimp culture cycle.

Regarding the life cycle inventory (LCI) analysis, it was analyzed to understand all the stages of data collection and management, which are a conjunction of inputs and outputs related to the function or product generated by the process, based in a general way on making a balance of flows of both the products and the energy that enters and leaves a respective system. during its lifespan (Bernal & Rugeles, 2015).

The tool used for the development of this study is the inventory analysis, whose objective is to collect all the information of the unitary processes of the product system and relate them to the functional unit of the study. That's what it's for Bernal & Rugeles (2015), indicate that the following steps should be taken:

1. Collect all data, including all inputs and outputs of production system processes (such as product, process, and natural flows);

2. Define what will be the functional unit so that all the data collected are quantitatively related to the quantitative output of the product under study, normally it is 1 kg of product;

3. Then allocate or distribute the emissions and resource extractions of a given process over the functions that such a process can perform;

4. And finally, the evaluation of the data in a quantitative way.

As far as impact analysis is concerned Anton (2004) It indicates that during this phase it is allowed to establish the mandatory and optional elements, considering the following criteria:

1. Select impact categories, indicators for category, and models;

2. Classification: In this stage, the data obtained from the inventory are designated and applied in the categories according to the environmental effects produced during the production process;

3. Characterization: characterizes the data obtained in the categories according to the type of impact such as acid emission and acidification that allows the application of environmental interventions with precision and validity;

4. Standardization: This step is considered optional within the EICV. which involves an evaluation of the significance for the environmental profile that was generated by a "sizing" of the categories, comparing values of the above for a set of global activities, country, or region where the study was carried out Anton (2004).

After having processed all the information, the results obtained from the inventory analysis are integrated with the evaluations that determine the impacts, these results are expressed as conclusions and recommendations with the purpose of carrying out actions and considering in which process of the shrimp life cycle environmental emissions are produced and according to the data establish which phase of the procedure evaluated the opportunities for improvement (Rieznik & Hernandez, 2005).

3. RESULTS

The purpose of the following study is to determine the critical points generated from the cultivation and production of shrimp of the species Litopenaeus Vannamei in the province of Guayas by means of LCA.

A functional unit was considered to be "1 kg of frozen shrimp packed at the exit of the door of the packing house located in the province of Guayas".

The present study establishes the limits "from cradle to door" from shrimp culture to its exit from the packing house, whose processes are described in Figure 1, in which all the stages through which the shrimp pass until its exit from the processing factory can be visualized.

The period of data collection and development of this study corresponds to the rearing of shrimp in the pools, establishing the data collection in a period of 3 months.

By means of life cycle analysis, data obtained from research in a shrimp farm and a packing house located in the province of Guayas have been analyzed.

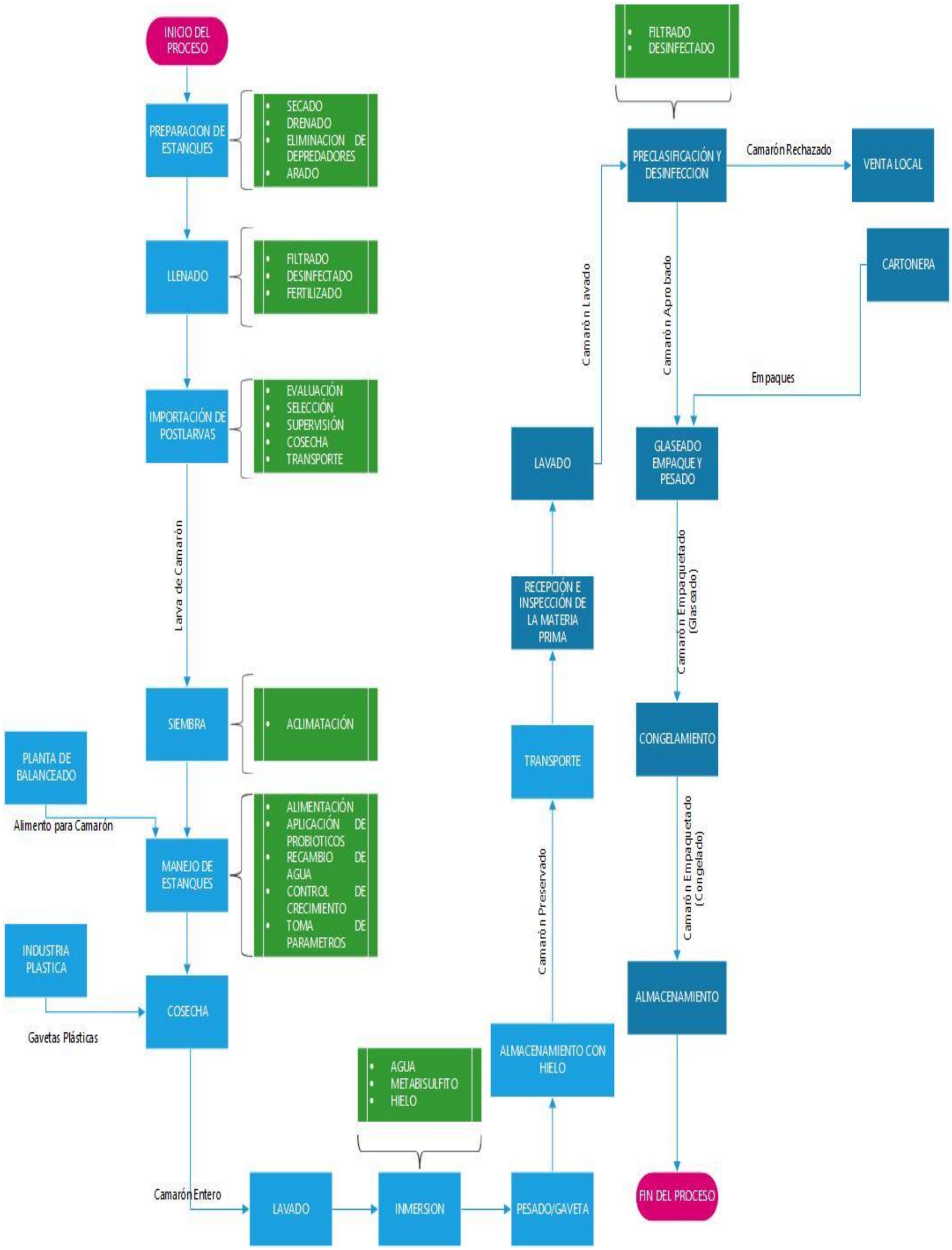

Figure 1 Shrimp Life Cycle

Source: Bastidas & Moreira, 2021

3.1 Inventory analysis

3.1.1 Data Quality

Data collection was carried out from direct sources of information: interviews and water sampling; The sampling consisted of data collection from the water analysis at the outlet of 1 pool inside the shrimp farm and at the outlet of the process at the packing house; Regarding the interviews conducted in the shrimp farm, important information was obtained about the feeding and care of the shrimp; while in the packing house, the information on the storage and processing of shrimp from arrival at the industry to final dispatch as a frozen product.

The analysis of the data from the inventory is processed by the OPEN LCA program, for this it is necessary to have a complete database, which allows categorizing each of the impacts, quantifying and classifying them according to their percentage of contribution for each of the processes.

3.1.2 Data Source

Tables 1, 2 and 3 show the data sources used within the study using Ecoinvent 3.7.1

Feed Data Source

Table 1. Summary of processes taken from the Ecoinvent database (Feed)

Input/output inventory item	Ecoinvent database
Electrical energy	market for electricity, low voltage | electricity, low voltage | APOS, U – EC
Fish oil	Fishmeal and fish oil production, 63-65% protein, from fresh anchovy | fish oil, from anchovy | APOS, U – PE
Fish oil	Fishmeal and fish oil production, 65-67% protein | Fishmeal, 65-67% protein | APOS, U – PE
Corn kernels	Maize Grain, Feed Production | Maize Grain, feed | APOS, U – RoW
LPG	Market for Propane, burned in building machine | Propane, burned in building machine | APOS, U – GLO
Soybean meal	Market for Soybean Meal | Soybean Meal | APOS, U – RoW
Wheat flour	Market for Wheat Flour | Wheat Flour | APOS, U – RoW

Source: Compiled by the authors using the tool (OpenLCA, 2021)

Farming data source (shrimp farm)

Table 2. Summary of processes taken from the Ecoinvent database (Cultivation)

Input/output inventory item	Ecoinvent database
Organic Acids	Market for Citric Acid | Citric Acid | APOS, U – GLO
Electrical energy	market for electricity, low voltage | electricity, low voltage | APOS, U – EC
Fertilizers	ammonium nitrate phosphate production | nitrogen 1258ertilizer, as N | APOS, U – RoW
Diesel	market for diesel, burned in building machine | diesel, burned in building machine | APOS, U – GLO

Source: Compiled by the authors using the tool (OpenLCA, 2021)

Baler Data Source

Table 3 Summary of processes taken from the Ecoinvent (Baler) database

Input/output inventory item	Ecoinvent database
Electrical energy	market for electricity, low voltage | electricity, low voltage | APOS, U – EC
Ice	Ice process
Gloves	Market for Latex | Latex | APOS, U – RoW
Plastic sleeves	Market for Packaging Film, Low Density Polyethylene | Packaging film, low density polyethylene | APOS, U – GLO
Masks	polypropylene production, granulate | polypropylene, granulate | APOS, U – RoW
Tags	Offset printing, per kg printed paper | printed paper, offset | APOS, U – RoW
Boots	Synthetic rubber production | synthetic rubber | APOS, U – RoW
Cardboard boxes for packaging	Market for carton board box production, with

	gravure printing | carton board box production, with gravure printing | APOS, U – GLO
Drinking water	Market for Tap Water | tap water | APOS, U – CO
Shrimp heads	treatment of municipal solid waste, sanitary landfill | Municipal Solid Waste | APOS, U – RoW

3.2 Inventory of inputs and outputs

Within the purpose of the Life Cycle Assessment (LCA) is to analyze the results through inventories referred to by the inputs and outputs of each of the stages that are carried out during the production of Ecuadorian shrimp, in order to know the environmental impact generated in said production (Anton, 2004).

In the life cycle inventory of this study, it presents the inputs and outputs of the materials and the energy flows of the processes, obtaining an evaluation and recognition of the significant environmental impacts of the life cycle of the product (shrimp).

Each of the data was obtained through visits and interviews with the responsible personnel of accredited laboratories.

3.2.1 Inventory sheet of inputs and outputs

Table 4 shows the inventory of inputs and outputs of inputs and outputs to obtain post-larvae necessary to carry out the production of the functional unit (1 kg).

Table 4 Inventory of inflows and outflows of the larval hatchery process

Tickets		
Flow	**Unit**	**Quantity**
Nauplius	Kg	1
Electrical energy	Kw*h	431,53
Diesel	Kg	0,82
Vitamin C	Kg	0,75
Magnesium	Kg	0,75
Potassium	Kg	0,43
Molasses	Kg	0,33
Feeding	Kg	14,25
Freshwater	Kg	148,35
Outputs		
Flow	**Unit**	**Quantity**
Post larvae	Kg	1

Prepared by: Bastidas & Moreira, 2021

Table 5 presents the inventory of the inputs and outputs of each of the inputs and products necessary for the production of one kilo of balanced feed, it is worth mentioning that the feed has 35% protein, being one of the percentages with the highest demand in terms of use during the cultivation stage (shrimp farm). due to the benefit that the assimilation of the food is much better. On the other hand, the gas used to operate the boilers during the feed process is LPG.

Table 5 Inventory of Inputs and Outputs of the Balancing Process

Tickets		
Flow	**Unit**	**Quantity**
Electrical energy	Kw*h	0,064
LPG	Kg	0,01
Fishmeal	Kg	0,46

Wheat flour	Kg	0,26
Soybean meal	Kg	0,13
Corn	Kg	0,22
Fish oil	Kg	0,030
Outputs		
Flow	**Unit**	**Quantity**
Balanced for shrimp	Kg	1

Prepared by: Bastidas & Moreira, 2021

Table 6 presents the inventory of the inputs and outputs of the products necessary to obtain one kilogram of ice used within the packing process to maintain the cold chain of the product already packaged.

Table 6. Ice Process Input and Output Inventory

Tickets		
Flow	**Unit**	**Quantity**
Electrical energy	Kw*h	0,14
Water	Kg	2,33
Outputs		
Flow	**Unit**	**Quantity**
Ice	Kg	1

Prepared by: Bastidas & Moreira, 2021

Table 7 presents the inventory of the inputs and outputs of the inputs needed to carry out the production of one kilogram of live shrimp at the exit of the farm. These data were obtained through visits to the shrimp farms in conversations with biologists or field managers, samples were also collected for water quality analysis in an accredited laboratory. It should be noted that the inputs could vary depending on the protocols established by each field manager.

Table 7 Inventory of inputs and outputs of the production process in culture (shrimp farm)

Tickets		
Flow	**Unit**	**Quantity**
Post Larva	kg	2,315E-07
Balanced	kg	1,5000003
Electrical energy	kW*H	0,0077162
Diesel	kg	0,1322774
Organic Acids	kg	0,0011023
Fertilizers	kg	0,0165347
Bacteria	kg	0,0826734
Freshwater	m3	5,511558
Outputs		
Flow	**Unit**	**Quantity**
Whole Shrimp	kg	1
Emissions to water		
Hexavalent Chromium	kg	6,945E-14
Chemical Oxygen Demand	kg	2,237E-09
Biochemical Oxygen Demand	kg	1,119E-09
Total Phosphorus	kg	5,598E-13
Nitrate	kg	1,451E-12
Nitrite	kg	2,772E-13
Ammonia Nitrogen	kg	9.33E-13
Total Nitrogen	kg	5,909E-12

Total Suspended Solids	kg	2,115E-11
Sulphates	kg	1,354E-10
Total Solids	kg	4,413E-08
Air emissions		
CO_2 emissions	kg CO_2	0,3465486
CH_4 Emissions	kg ch_4	0,3821793

Prepared by: Bastidas & Moreira, 2021

Table 8 presents the inventory of inputs and outputs during the packing process, obtaining one kilo of packed tail shrimp with its respective freezing. The data has been obtained through the process of a complete batch, processing 1814.37 kilos of whole shrimp.

Table 8 Input and Output Inventory of the Packed Shrimp Production Process

Tickets		
Flow	**Unit**	**Quantity**
Whole shrimp	Kg	1,51
Shrimp Packing Boxes	Unit	0,52
Shrimp Packing Boxes	Kg	0,063
Plastic sleeves	Kg	0,0012
Ice	Kg	0,41
Water	Kg	18,18
Electrical energy	Kw*h	2,42
Tags	Kg	0,0012
Gloves	Kg	0,0062
Boots	Kg	0,046
Masks	Kg	0,00018
Outputs		
Flow	**Unit**	**Quantity**
Packaged tail shrimp	Kg	1
Shrimp heads	Kg	0,52
Emissions to water		
Ammonium	Kg	1,851E-05
Nitrite	Kg	1,937E-06
Phosphorus	Kg	8,609E-05
COD	Kg	0,00026
Fats	Kg	0,0019

Prepared by: Bastidas & Moreira, 2021

3.3 Life Cycle Impact Assessment

In life cycle analyses, an impact is considered as the anticipation of an effect, since the purpose is not to determine the category to which it belongs, but to link the data obtained in the inventory study with an impact category, quantifying the contribution that it provides to each of them (Regueriro Rubio, 2012).

To carry out the impact assessment process, three relevant categories have been selected within the Open LCA program, to establish the possible impacts obtained through the inventory data mentioned below:

The CML200 method provides a list of categories grouped into "mandatory", "additional" and for those indicators that exist but are not frequently included in stroke studies (Feijoo, 2020).

When selecting the impact categories, it is necessary to take into account which are the most relevant, which allow the impacts produced by the data obtained during the inventory analysis to be covered (Regueiro, 2012).

The categories analysed in this study are detailed below:

Table 9. Impact Categories

Categories	Description	Unit
Climate Change GWP	Indicator of potential global warming due to greenhouse gas emissions into the atmosphere or climate change (Henry Benavides & Gloria León, 2007)	Kg CO2-Eq
Terrestrial acidification TAP	The acidification process, also called "acid rain", originates when sulphur, which is found in an elemental state in fossil fuels, and nitrogen, present in the air and fuels, are released into the atmosphere after combustion processes, in the form of nitrogen oxides (NOx) and sulphur dioxide (SO2) ("The acidification of the environment - Generalitat Valenciana," 2015).	Kg SO2-Eq
Freshwater eutrophication FEP	Eutrophication of freshwater occurs due to the discharge of nutrients into the soil or freshwater bodies and the consequent increase in nutrient levels (i.e., phosphorus and nitrogen) ("Eutrophication: Causes, Consequences, and Solutions | iAgua," 2018).	Kg P-Eq

Prepared by: Bastidas & Moreira, 2021

3.3.1 Contribution Analysis (Contribution of 1 kg of live shrimp)

The results of the contribution of the processes to the impact categories in the stage of obtaining 1kg of live shrimp from the farm indicate that the main process that has a significant impact on the categories originates in the production of meals (soybeans, wheat and fish including fish oil) contributing 57.36% to the terrestrial acidification category. followed by the 58.26% contribution to climate change and finally the eutrophication of brackish water 74.52%.

In second place is the use of diesel engines during the pumping of water into swimming pools, which contributes mostly to the acidification category with 26.08%, followed by climate change 25.84%, and to a lesser extent to the brackish water eutrophication category with 3.38%.

In terms of corn grain production, it contributes mostly to the acidification category with 20.43%, followed by 12.15% to climate change and 2.29% to freshwater eutrophication.

while ammonium nitrate and nitric acid used as compounds in the composition of farm-managed fertilizers contribute 3.74% and 0.56% for the freshwater eutrophication category; 1.38% and 0.33% to climate change; and 1.16% and 0.28% in terrestrial acidification.

While the use of gas for feed production contributes 3.09% to climate change, 0.56% eutrophication of brackish water and 0.88% acidification; and in relation to the use of electricity during cultivation, this represents 1.38% contribution to climate change, 0.40% eutrophication, 1.08% acidification of the land. Finally, it should be noted that in the larval production process the impacts are not significant.

Figure 2 represents the contribution of 1kg of live shrimp from the farm to the Climate Change indicator, the process with the highest score is the production of flour with 58.26% (soybeans with 25.53%, wheat with 16.47%, fish 16.26%), followed by 25.84% of the use of diesel engines and in terms of larval production the impact is not significant.

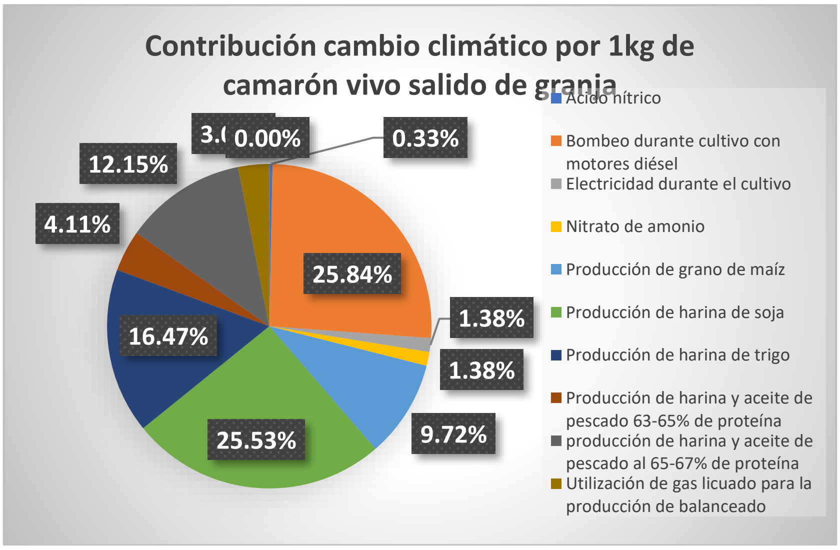

Figure 2 Climate change contribution per 1 kg of live shrimp left the farm

Source: Compiled by the authors using the tool (OpenLCA, 2021)

Figure 3 shows the contribution to the freshwater eutrophication indicator, whose contributions to this indicator derive mainly from the production of flour, followed by the production of corn grain, and finally, the use of diesel engines.

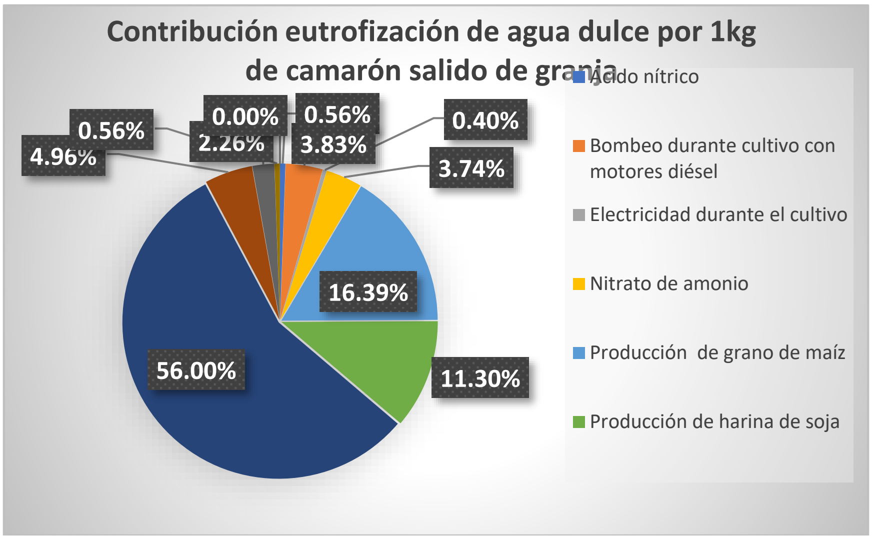

Figure 3 Contribution of freshwater eutrophication per 1 kg of live shrimp from the farm

Source: Compiled by the authors using the tool (OpenLCA, 2021)

The contributions to the terrestrial acidification category corresponding to Figure 4 are mostly represented by the total production of flours, followed by the use of diesel engines in the pools with 26.08%, and finally the production of corn grain.

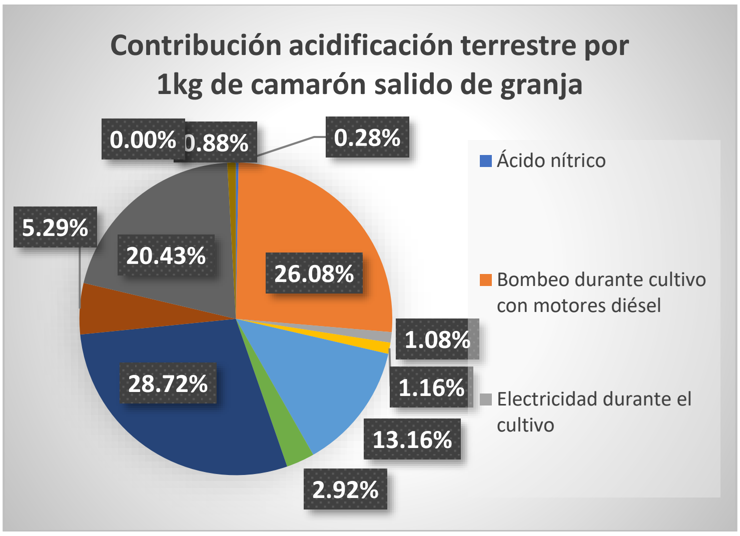

Figure 4 Contribution of terrestrial acidification per 1 kg of live shrimp from the farm

Source: Compiled by the authors using the tool (OpenLCA, 2021)

3.3.2 Contribution of 1 kg of feed

The contributions to the impact categories, derived from the shrimp feeding phase, show that:

The production of meals and oils has a significantly higher contribution value in the climate change indicator with 80.01%, followed by the category eutrophication of brackish water with 79.05% contribution; while 50.49% contributes to terrestrial acidification.

The production process of wheat and corn grains contributes mostly in the category of water eutrophication with 79.18%, while for the category of acidification it contributes 57.35%, this is due to the use of fertilizers in the stages of crop development and finally to climate change of 13.40% in the production of corn grain which originates from the use of agricultural machinery.

As for the use of gas and electricity during the production process of the balance, it contributes with 5.84% of climate change emissions; 2.51% to the process of terrestrial acidification and 0.61% to freshwater eutrophication; and during the transport stage of the balance, the contribution is low with 0.75% contribution to climate change, 0.50% acidification and 0.18% eutrophication of freshwater.

As can be seen in figure 5, during the shrimp feeding process, the contributions to the climate change indicator are mainly associated with the production of meals and oils, representing 80.01% of CO2 emissions, mainly associated with the production of soybeans and oils with 34.75%; wheat flour with 22.68%; fishmeal and fish oil at 63-65% and 65%-67% protein with 5.73% and 16.85%; the production of corn kernel represents 13.40%, in terms of the use of gas and electricity during the production process of the feed, this contributes with 5.84%; while during the transport stage of the balance, the contribution is low at 0.75%.

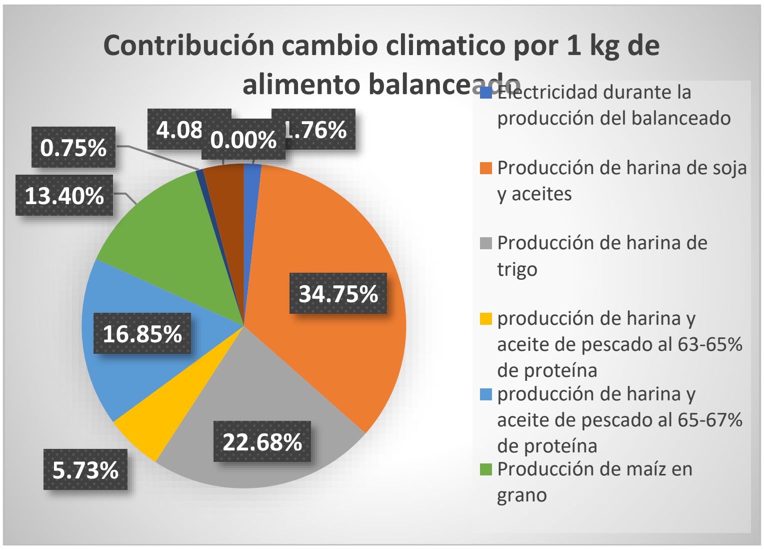

Figure 5 Climate change contribution per 1 kg of feed

Source: Compiled by the authors using the tool (OpenLCA, 2021)

Figure 6 represents the contribution of shrimp feeding processes, the land acidification indicator is the largest contributor to the category, it is attributed to the production of grains (corn and wheat) with 57.35%, followed by the production of flour with 39.64%, the use of electricity and gas used in the production of feed represents 2.51%; Transport contributes 0.50%.

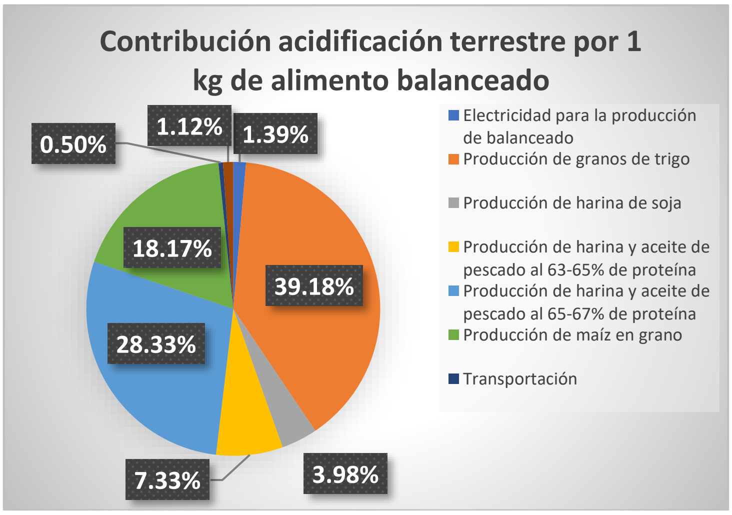

Figure 6 Contribution of land acidification per 1 kg of feed

Source: Compiled by the authors using the tool (OpenLCA, 2021)

Figure 7 shows that the contribution of wheat grain production to the eutrophication category is significantly higher with 61.30%, while corn grain has a value of 17.88%, in terms of flour production it contributes 20.03% of the substances caused by eutrophication in water.

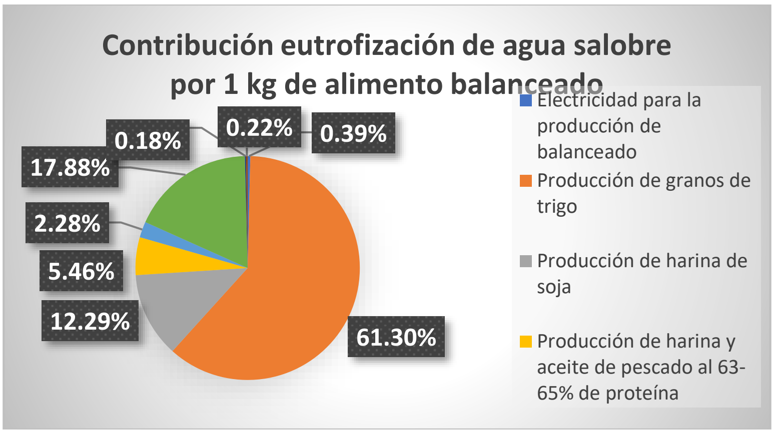

Figure 7 Eutrophication contribution of brackish water per 1 kg of feed

Source: Compiled by the authors using the tool (OpenLCA, 2021)

3.3.3 Contribution at the functional unit level

According to the results of contribution to the impact categories, it is evident that at the level of finished product in the shrimp cultivation or fattening stage, balanced feed contributes significantly to the climate change categories with 52.64% of contribution; eutrophication of brackish water 78.54% and acidification of the earth 59.57% and the use of diesel engines in pumping water into swimming pools represents an impact of 21.36% on acidification, with 21.36% followed by 18.72% contribution to the climate change category, and 3.32% to eutrophication.

Electricity used during cultivation and processing contributes 16.38% to climate change; It contributes 5.75% to freshwater eutrophication and 14.65% to land acidification. As for the water used for processing, the highest contribution is shown in the eutrophication category with 0.33%, followed by 0.22% for climate change and 0.15% in land acidification. Landfill processing waste contributes 6.05% to the climate change category, while 1.13% contributes to water eutrophication and 0.18% to acidification.

Materials such as rubber boots, latex gloves, cardboard, paper and packaging contribute 7.23% to eutrophication, and 4.35% contribute to climate change while 2.59% contribute to acidification. On the other hand, the ice used in the packaging-freezing process represents 0.37 percent of the contribution to climate change; 0.32% contribution to brackish water eutrophication and 0.06% acidification

Nitric acid and ammonium nitrate used during the shrimp farming process as one of the ingredients of fertilizers have the highest contribution with 0.47% and 3.16% to the eutrophication of brackish water; for climate change, it contributes 0.24% and 1.00%; In terms of acidification, nitric acid and ammonium nitrate provide 0.23% and 0.95%. On the other hand, the production of granulated polypropylene represents 0.01% of contribution to climate change and eutrophication indicators.

Figure 8 shows the contribution at the level of the functional unit, for the climate change indicator, the largest contributor to the category is attributed to the consumption of balanced with 52.64%, followed by the consumption of fuel (diesel) during pumping in the cultivation stage with 18.72%; Another important point is the use of electricity during cultivation, representing 16.30% and finally, with 6.05%, corresponds to the waste generated during processing deposited in landfills.

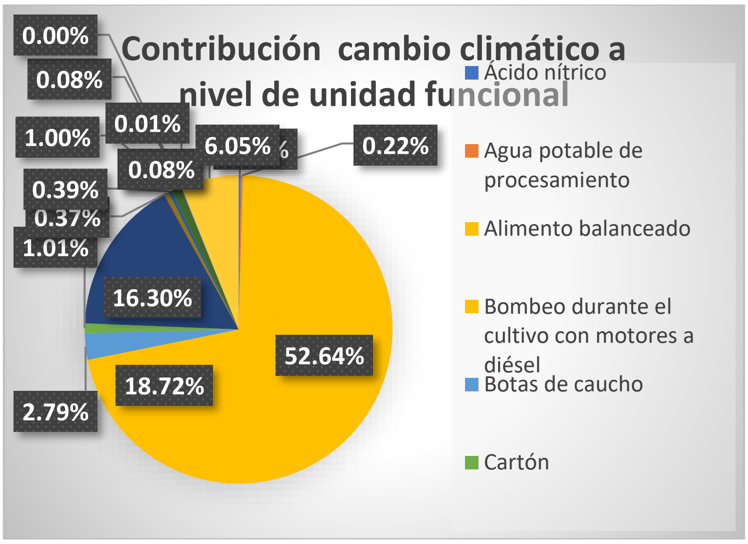

Figure 8 Climate Change contribution at the functional level

Source: Compiled by the authors using the tool (OpenLCA, 2021)

Figure 9 shows the contribution at the level of functional unit, for the eutrophication indicator, the largest contributor to the category is attributed to the consumption of balanced with 78.54%, followed by the use of electricity representing 5.72% during cultivation and 0.03% during processing, on the other hand 4.36% corresponds to the material of the boots (synthetic rubber) and finally with 3.32% to the consumption of fuel (diesel) during pumping at the cultivation stage.

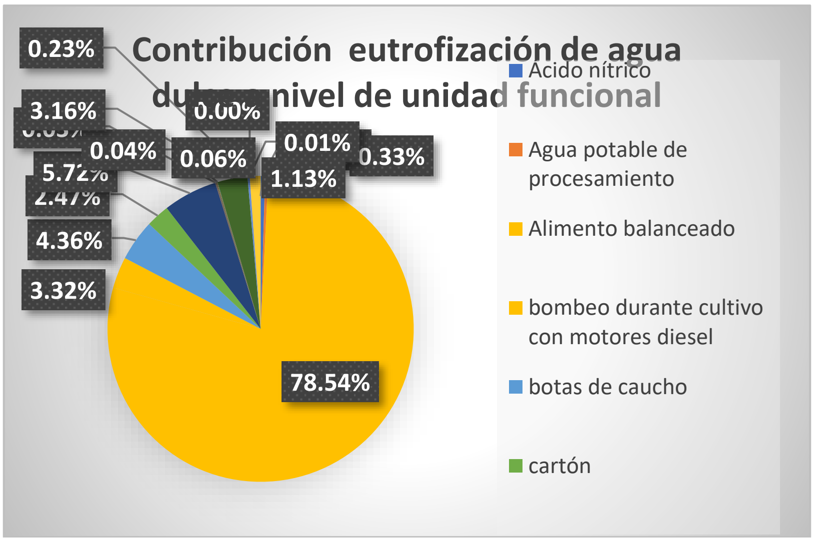

Figure 9 Contribution of water eutrophication at the functional unit level

Source: Compiled by the authors using the tool (OpenLCA, 2021)

Figure 10 shows the contribution at the level of the functional unit, for the acidification indicator, the largest contributor to the category is attributed to the consumption of balancing with 59.57%, followed by the consumption of fuel (diesel) during pumping in the cultivation stage with 21.36% and finally it is the use of electricity representing 14.58% during cultivation.

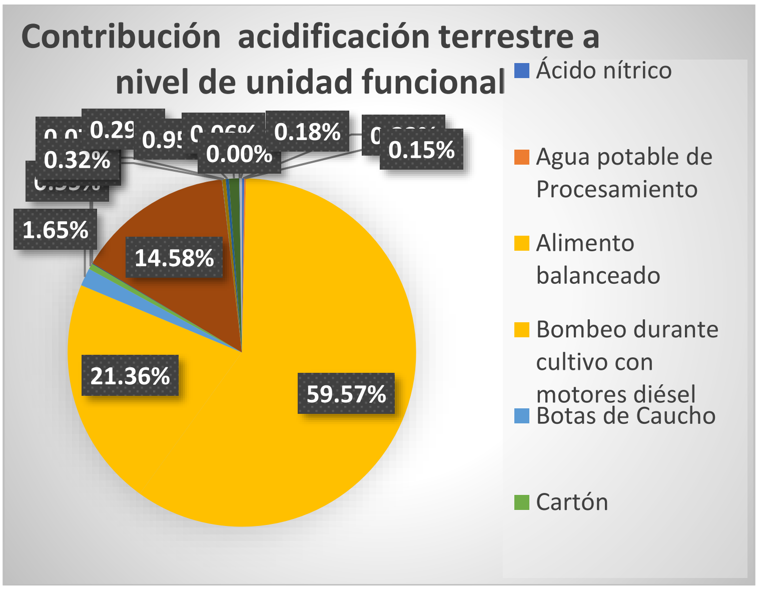

Figure 10 Contribution of brackish water eutrophication at the functional unit level

Source: Compiled by the authors using the tool (OpenLCA, 2021)

3.4 Comparison with other studies

According to Hernández & García (2015), in its life cycle analysis study of 1 kilo of shrimp as a functional unit, indicates that the stage that generates the greatest impact of shrimp cultivation or fattening (83-88%) derived from balanced feed is contributing 50% of the total whose impacts are mainly related to agricultural inputs and crop management; followed by transportation with a share between 7 and 12%, shrimp processing (4.4 and 4.7%), and finally the larviculture stage, contributing with 0.13-0.14% of the total, it also indicates that based on international studies, soybean, corn and wheat crops are highly impactful products.

According to Cao et al. (2011), in the evaluation of the parametric LCA of Chinese shrimp farming with reach from the cradle to the port of destination, it was determined that the contributions in the fattening phase in intensive systems represented between 69.4 to 96.8% and in semi-intensive systems 67.4 to 99.3% for each impact category; in turn in the processing stage in intensive systems represented between 0.9% and 15.6% and 0.6% to 26.8% in semi-intensive systems, as the contributions of larval production in hatcheries were negligible in both supply chains for all impact categories.

On the other hand, Ramírez & Duque (2008), for the functional unit of 2 kg of frozen shrimp, indicate that the greatest impact is generated in the pool culture stage, due to the use of land for agriculture in the cultivation of cereals necessary for the production of balanced feed and the emissions derived from fuel consumption during the use of diesel engines associated with water pumping and feed production.

Regarding the study of (Mungkung et al., 2006) Whose functional unit is defined by a 3 kg shrimp package, the results in the agriculture stage obtaining grains and cereals is the most significant, as for the farming stage on the farm the impacts are derived from the use of electricity and feed for the shrimp.

Considering that the functional units proposed by the authors are different, the present work agrees with the results of the aforementioned studies, indicating that the fattening stage of shrimp is the one that contributes significantly in the three impact categories. According to the results, the greatest contribution originates from balanced feed, which is associated with the production of grains and flours, contributing 52.64% climate change, 59.57% acidification and 78.54% eutrophication, where the production of soybean meal is highly impactful; in second place is diesel consumption with 3.32% contribution to eutrophication, 18.72% for climate change and 21.36% acidification; in third place is the use of electricity during cultivation and processing, contributing 5.75% to the eutrophication category, climate change to 16.38% and acidification 14.65%; On the other hand, it was evidenced that larval production is one of the least impactful phases of the entire life cycle.

4. CONCLUSIONS

Based on the results, it is concluded that the critical points that occur during the life cycle of 1kg of packed shrimp originate in the shrimp culture phase, specifically the production and consumption of feeding, followed by the consumption of fuels in the pumping of water.

The shrimp farming phase is the stage that contributes the most to the three impact categories analysed. This is mainly due to the consumption and production of feed in swimming pools, which contributes 52.64% to climate change, 78.54% to eutrophication and 59.57% to acidification; In terms of fuel consumption for the same phase, it contributes 18.72% to climate change, eutrophication 3.32% and acidification 21.36%; whereas, the impact of larval production is negligible for all categories.

In the production of balanced feed linked to the cultivation stage, the process that has a significant impact on the categories of climate change, eutrophication and acidification, is due, in the first place, to the production of flours, mainly soybean meal, which contributes in the aforementioned categories with 34.75%, 61.30% and 39.18%; followed by wheat flour with 22.68%, 3.98% and 12.29%; while in the production of fishmeal and oil it contributes 22.58%, 35.66% and 7.74%. In second place is the production of maize grains with 13.40%, 18.17% and 17.88% contribution; and grain production, wheat 39.18%, eutrophication and acidification 61.30%.

In processing, the impacts are generated in the aforementioned cultivation stages, followed by the use of electricity, which contributes 16.38% to climate change; It contributes 5.75% to freshwater eutrophication and 14.65% to land acidification, while the materials used during processing contribute 7.23% to eutrophication, and 4.35% contribute to climate change while 2.59% contribute to acidification.

With respect to the categories of impact for climate change, it is influenced by the emissions derived from the use of diesel, similarly for the category of acidification it is linked to the consumption of diesel and feed, and for eutrophication it is influenced by the consumption of balanced feed associated with the management of agricultural crops and due to the accumulation of nitrogen and phosphorus in the water from swimming pools.

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