TERUEL HAM LIFE CYCLE

ANALYSIS (LCA)

JAMONES SIERRA PALOMERA

TABLE OF CONTENTS:

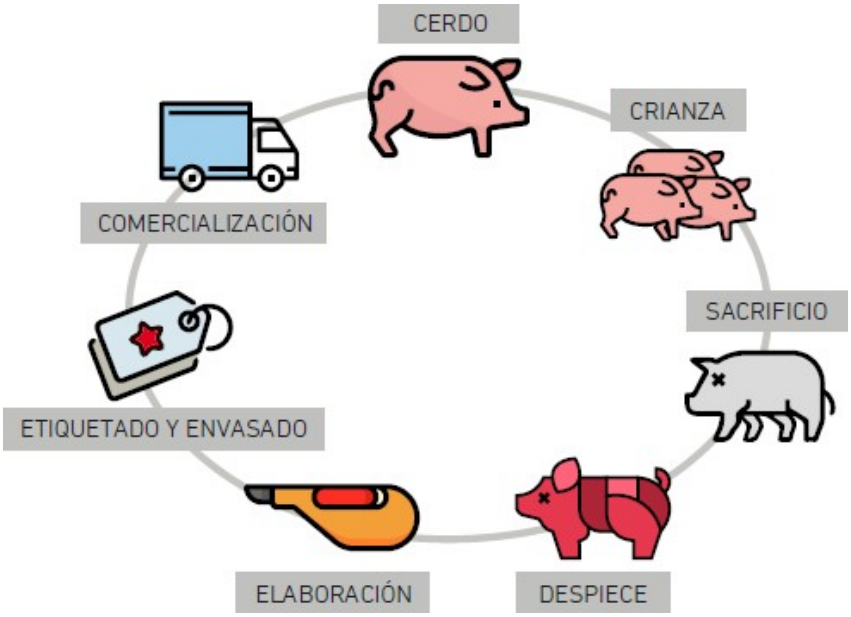
1. BACKGROUND AND RATIONALE

Life Cycle Analysis (LCA) is an analytical work methodology that makes it possible to analyse all a product's environmental loads by means of identification and quantification of matter and energy, thereby determining the impact and the emissions to subsequently set out improvement strategies. This analysis is used to analyse the system parts in an attempt to get results that reflect the potential environmental impacts and determine strategies to lighten them.

These elements are:

- **Inputs**. Product, material or energy flow entering a unitary process. In other words, the use of resources, raw materials, transport, electricity, energy, products, etc. that are used in each of the system processes.
- **Outputs.** Product, material or energy flow leaving a unitary process. Emissions to the air, water and soil, plus release of waste and subproducts during the system phase.

Therefore, the LCA considers the entire cycle for a product, process or activity, from its origin as raw material to its end of life as waste.



Regarding the **Carbon Footprint**, this is one of the main indicators to measure the impact or the impression left by an individual, organisation, product or event on the planet, as a consequence of their daily activity. The Carbon Footprint is defined as the tally of all the greenhouse gases (Gg) directly or indirectly released by a specific individual, organisation, event or product, and expressed in units of equivalent carbon dioxide (CO_2-eq).

In its commitment to sustainability and to fighting climate change, **the Protected Designation of Origin of "Jamón de Teruel"/ "Paleta de Teruel"** became the first Protected Designation of Origin in the Spanish meat sector to analyse the life cycle of its Designation of Origin products and target a zero-carbon footprint.

These are the various strategies, standards and plans managed throughout the world:

- New Urban Agenda for Sustainable Development.
- United Nations Sustainable Development Goals.
- European Circular Economy Strategy.
- Spanish Bioeconomy Strategy 2030.
- "Aragon Circular" Strategy.
- Climate Pact. Decarbonisation strategy for the economy.

Sustainability is thereby incorporated into the business strategy, making it an opportunity for change and transition towards a new way of doing business, while also protecting the environment.

2. INTRODUCTION

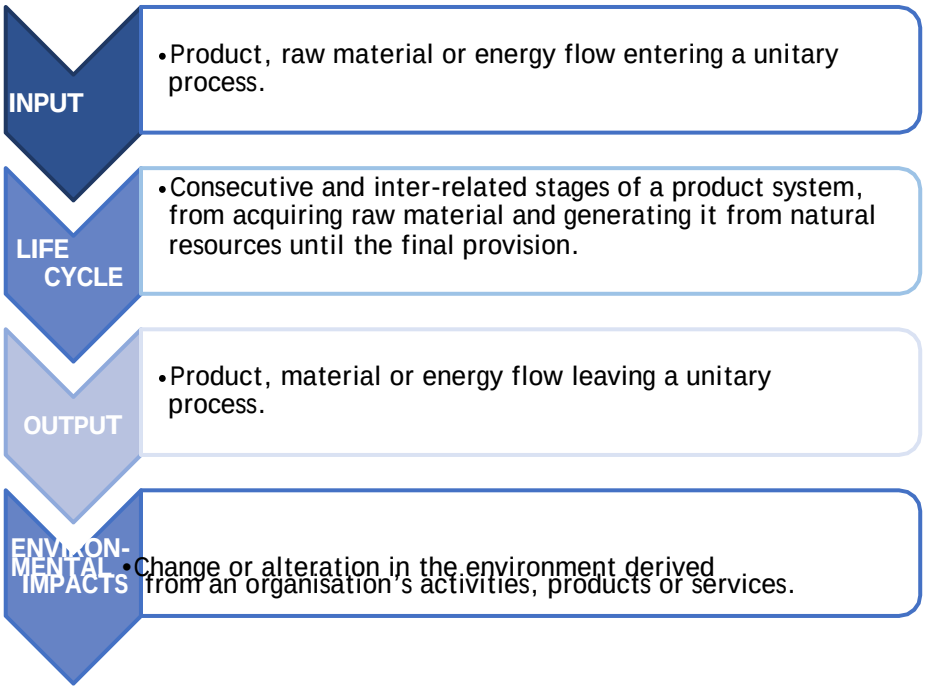
The **Protected Designation of Origin "Jamón de Teruel"/ "Paleta de Teruel"**, recognised as a PDO since 1983, is one of the province's main economic motors, creating a backbone throughout the territory, encouraging rural development and settling the population.

The main objective of this study is to consider all the ham-making processes, considering each input and output throughout the product life cycle, from its origin (raw material) to the end of the process (product) to also calculate the **Carbon Footprint, Water Footprint** and **Environmental Footprint** during the product life cycle.

To do so, the product system is analysed as the set of stages within the life cycle in the study. In other words, the set of connected unitary processes that carry out one or more functions. In addition, the system limits are set as the phases considered in the study and the criteria for each phase.

The stages that are quantified in this analysis make up the product's **Life Cycle**:

1. **Acquisition of raw material.** Stage that includes the activities required to acquire raw material and energy up to the first manufacturing phase or material processing phase.
2. **Manufacturing, processing and formulation.** Phase that groups together stages that range from introducing the raw material to obtaining the final product.
3. **Distribution and transport.** The distribution phase analyses the point when the manufactured products leave the factory and are sent to the end user. Regarding transport, this phase covers the movement of materials or energy in any life cycle phase.
4. **Use/Reuse/Maintenance.** The limits cover distribution of products or materials and finish when they become waste.
5. **Recycling.** This contains the activities necessary to store waste and return it to the manufacturing process.
6. **Waste management.** Stage including the waste treatment mechanisms.



Therefore, the aim of this LCA is to identify opportunities for improvement and reduce impacts in all ham manufacturing process activities.

3. GENERAL AIMS OF THE PROJECT

Aware of climate change and the effects on the environment, the "Jamón de Teruel"/ "Paleta de Teruel" Protected Designation of Origin intends to examine its emissions situation to be able to implement various action measures to reduce these emissions.

Product analysis aims to implement a sustainability strategy with the following objectives:

- Contribute to 2030 Agenda goals: Sustainable Development Goals.
- Make progress on the Bioeconomy challenges in Aragon and Spain.
- Increase sustainability using various indicators (carbon footprint, water footprint and environmental footprint).
- Increase companies' resilience to climate change.
- Change the paradigm for the sector regarding sustainability.

Consequently, this study aims to analyse the greenhouse gas emissions (GgE) derived from ham production in the province of Teruel. The phases/stages of ham/shoulder production are livestock, abattoir and drying area.

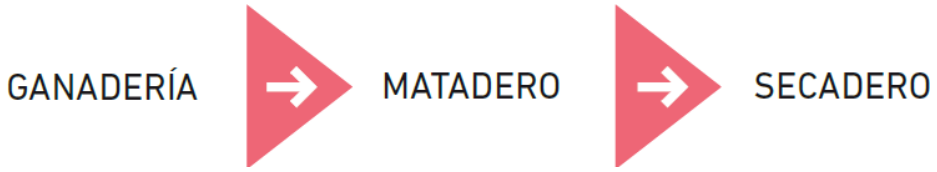


Illustration 1: Product Life Cycle Stages.
Source: Compiled by author.

However, the case of **Sierra Palomera** exclusively gives the drying stage, explaining why this study only analyses this stage.

4. PROTECTED DESIGNATION OF ORIGIN (PDO) "JAMÓN DE TERUEL"/ "PALETA DE TERUEL"

The hams and shoulders from the "Jamón de Teruel"/ "Paleta de Teruel" Protected Designation of Origin are meat products obtained after subjecting the front and rear limbs of the animal to various production processes. The main features are given below:

- **Morphological features.**
  - **Shape.** Long, profiled and rounded on the edges up to the appearance of the muscle, keeping the foot on. It can be covered with the whole crust or shaped into a V-cut aligned with the axis of the ham foot or the cured shoulder.
  - **Weight.** No less than 7 kg for hams and 4.5 kg for cured shoulders, after completing the minimum set production time.
- **Sensory features.**
  - **Colour.** Red and shiny when cut, with partially infiltrated fat in the muscle mass.
  - **Meat.** Delicate, only slightly salty flavour.
  - **Fat.** Unctuous consistency, shiny, white-yellow colouring, aromatic and a pleasant flavour.

Regarding the production zone, this is the province of Teruel, which is where the ham is made, and the drying area must be at an altitude of no less than 800 metres above sea level.

The process for making the PDO "Jamón de Teruel"/ "Paleta de Teruel" is as follows:

- **Salting** Adding salt to the muscle mass, to encourage dehydration of the legs and preserve them successfully. The salt remains in contact with the pieces between 0.65 and 1 day per kg of fresh leg or shoulder.
- **Washing**. The parts are washed with water to remove any salt stuck to them.
- **Settling or post-salting**. The salt diffuses inside the pieces of meat, slowly and gradually eliminating the water. The process takes place in chambers at a maximum temperature of 6ºC and relative humidity of no less than 70%. The time spent in the chambers depends on the weight of the pieces. It should be at least 60 days for hams and 30 days for shoulders.
- **Curing (drying and maturing)** This operation takes place in natural drying spots with the atmospheric conditions of the zone, and with features that allow ventilation to be controlled and so also the optimum relative humidity and temperature. To standardise and facilitate maintenance of these conditions throughout the drying spot and so that ventilation reaches all the product equally, irrespective of its location in the drying spot, the drying premises can be equipped with suitable devices, to maintain the right thermohygrometric level, whose pumping, extraction and recirculation or containing functions make it easier to distribute air inside, in all zones, thereby maintaining the same conditions for the whole product.
- **Ageing.** This is the phase where the biochemical reactions take place, responsible for the characteristic aroma and flavour. The minimum duration for the whole manufacturing process is 60 weeks for hams and 36 weeks for shoulders.

The quality of the PDO "Jamón de Teruel"/ "Paleta de Teruel" comes down to the animal's conditions during and after slaughter, the geographic area where it is bred, slaughter and place where the hams and shoulders are made. Therefore, product characteristics are particularly due to natural factors such as geographic relief, climate or human factors.

The specific nature of the product highlights:

- The **Duroc** race which is characterised by its optimum speed of growth, high rusticity, good prolificity and considerable feed yield. The meat from this race boasts greater fat infiltration which gives high quality meat.
- The **Landrace** is an animal above average size that, due to its dimensions, plays an important role in obtaining pigs for the Protected Designation of Origin. This race stands out for its excellent composition, its high daily weight gain, high transformation rate and its thick back fat.
- The **Large White** race adapts easily with good rusticity, fecundity and high fertility, with good technical transformation and growth rates, and its excellent quality meat, fundamentally defined by its juiciness, texture, composition and colour.

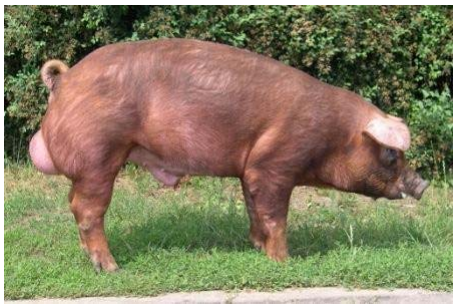


Image 1: Duroc
Source: Ministry of Agriculture, Fisheries and Food.

Image 2: Landrace.
Source: Ministry of Agriculture, Fisheries and Food.

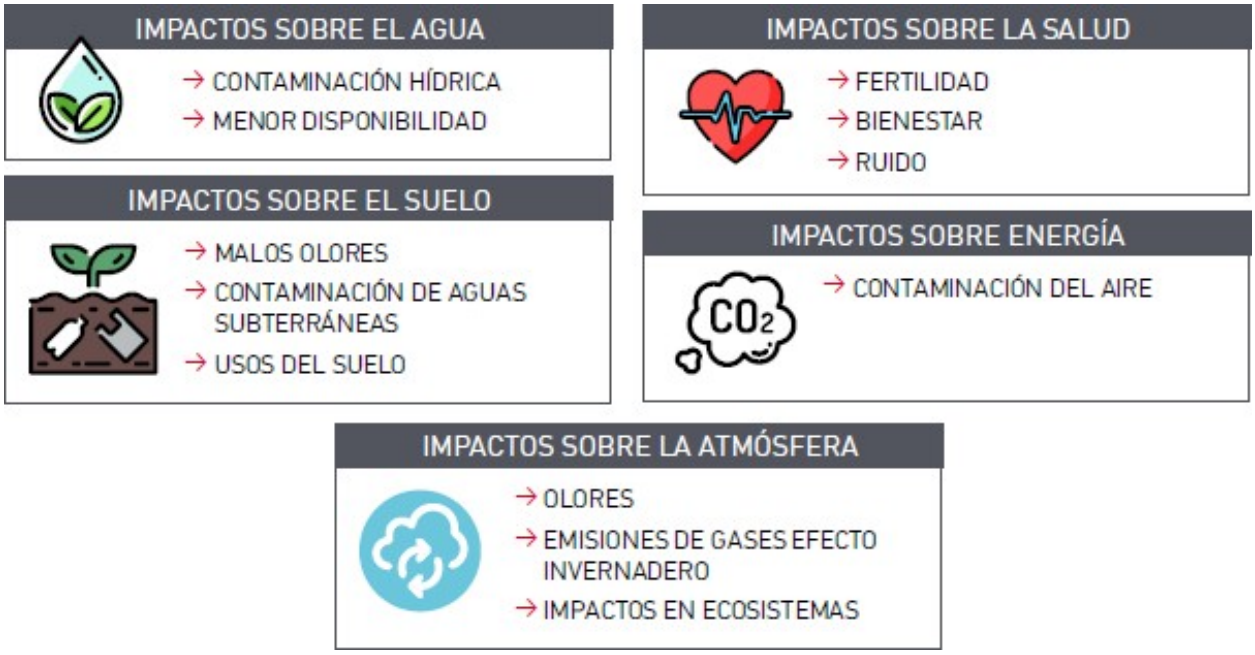
Image 3: Large White.
Source: Ministry of Agriculture, Fisheries and Food.

5. ENVIRONMENTAL IMPACT OF THE SECTOR

Having determined the processes within the sector, just like all the inputs and outputs for each of the activities, both the direct and indirect environmental impacts are highlighted, associated with acquiring raw materials, consumption of products and energy consumption.

This identifies environmental impacts by studying interactions between the activities being performed.

The main environmental impacts in the sector are identified below:



6. DESCRIPTION OF THE COMPANY AND PRODUCT

La **Estrella del Jamón** is the name that encompasses Mariano Gómez, S.A. and Jamones Sierra Palomera, S.L. companies, a family firm that makes Protected Designation of Origin "Jamón de Teruel"/ "Paleta de Teruel" (Teruel Ham and Pork Shoulder) and Serrano Hams cured in natural drying areas. Hand-crafted.

The common name of La Estrella del Jamón covers three brands:

- Sierra Palomera.
- Sierra Lindón.
- Mariano Gómez.

Teruel"/ "Paleta de Teruel". Source: La Estrella del Jamón website.

The drying spot is in Monreal del Campo, at 940 metres above sea level, giving the product singular characteristics. Its location means that the cold is dry, thereby encouraging natural, slow and lengthy curing, lasting more than 18 months.

7. LIFE CYCLE ANALYSIS METHODOLOGY

7.1. LIFE CYCLE ANALYSIS (LCA)

As compiled in the **ISO 14040:2006 standard** (Environmental management. Life cycle analysis. Principles and frames of reference), the life cycle concerns the consecutive and inter-related stages of a product system, from acquiring raw material and generating it from natural resources until the final provision. In this way, the **Life Cycle Analysis (LCA)** compiles and assesses all the inputs, outputs and potential environmental impacts of a system for the product through its life cycle.

Therefore, the LCA considers the complete life cycle of a product, from extraction and acquisition of the raw material, also involving production of energy and material, and manufacturing, up to the use and final processing of the useful life and final provision. Through this general vision and system perspective, it is possible to identify and possibly avoid displacement of a potential environmental load between life cycle stages or individual processes.

To do so, the system parts are analysed in an attempt to get results that reflect the potential environmental impacts and determine various strategies to lighten them.

The reference standards to perform the LCA are:

- **UNE-EN-ISO14040: 2006 standard**. Environmental management. Life cycle analysis. Principles and frame of reference.
- **UNE-EN-ISO 14044:2006 standard.** Environmental management. Life cycle analysis. Requirements and guidelines.

The Life Cycle of a product can have different scopes, and the most common are defined below:

Gate to gate

- This considers the activities (productive process) of the company to which it is applied.

Cradle to gate

- This considers the activities from extraction and conditioning of raw materials to the company's production process.

Gate to grave

- This considers the company's productive process and covers up to the phase managing the waste resulting from the product.

Cradle to grave

- It analyses from conditioning of raw materials up to final waste management.

Cradle to cradle

- This covers the entire product life cycle, from conditioning of raw materials until the product is put back into the same production process or another one.

In this case, it could be said that the scope of this LCA is **Cradle to Gate**, as it is an intermediate analysis of the product life cycle, considering the inputs, outputs and impacts. In general, there are various phases to an LCA:

- **Phase to define the Goal and the Scope**, including the system's limits and the level of detail, depending on the topic and use of the study.
- **Phase to analyse the Life Cycle Inventory (LCI)** Second phase of the LCA. Inventory of input/output data in relation to the system being studied. This involves compiling the data required to meet the study goals.
- **Phase to Assess the Life Cycle Inventory (LCIA)** Third phase of the LCA. Assessment of a system's life cycle inventory results for a product with the aim of understanding its environmental importance.
- **Interpretation of the life cycle.** Final phase. Stage which summarises and discusses the results and draws conclusions, makes recommendations and decisions.

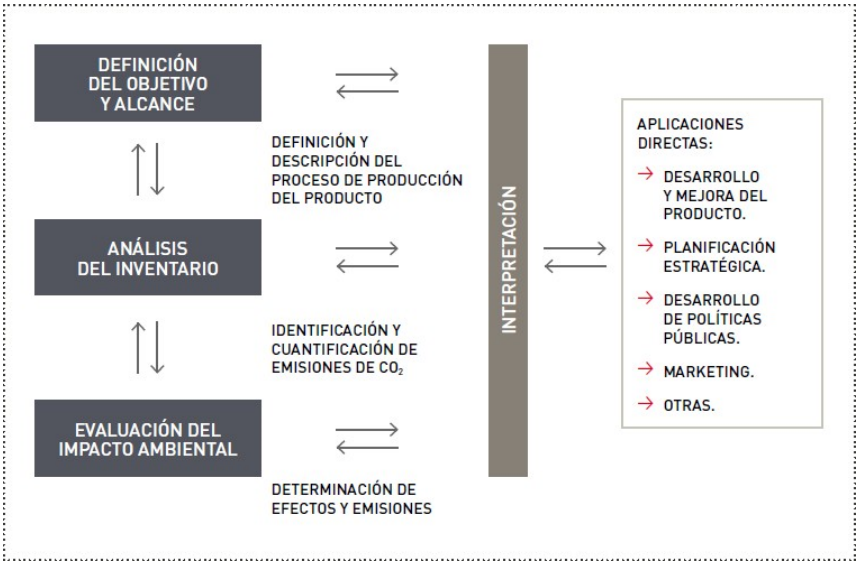


Illustration 2: Stages of an LCA.

Source: Own work from information obtained in the ISO 14040:2006 standard.

In this way, although all LCAs include the same stages, the level of detail depends on the study goal. This means that there are three types of LCA:

- **Conceptual LCA.** Qualitative study with the main goal of identifying the most relevant potential impacts.
- **Simplified LCA.** This LCA carries out selective analysis of the most generic data that addresses the Superficial Life Cycle.
- **Complete LCA.** Detailed qualitative and quantitative analysis of both inventory and the impacts.

A **Complete LCA** is used to analyse Teruel Ham, thereby running a detailed qualitative and quantitative analysis of the inventory and impacts. Consequently, the input and output data are quantified by the different companies that take part in the project while, on the other hand, these data are analysed by a multidisciplinary team to weigh up the magnitude of the environmental impacts derived from making the product.

The LCA helps to:

- ✓ Identify opportunities to improve the environmental performance of the products in the various stages of their life cycle.
- ✓ Provide information for decision-makers in the industry, governmental or non-governmental organisations.
- ✓ Select relevant environmental performance indicators, including measuring techniques.
- ✓ Marketing

7.2. SCOPE OF THE LCA

As mentioned previously, the LCA for "Jamón de Teruel"/ "Paleta de Teruel" is based on a Complete LCA methodology, to explore all the inputs and outputs of each process in the life cycle of a piece of ham. In this way, the scope is "Cradle to Gate" as the study excludes the product's marketing, distribution and consumption (end of life) processes plus business and employee travel.

Therefore, the ham passes through various stages. Firstly, there is the livestock phase, split into nursing and fodder stages. Once the pig's rearing stage is over, it is transported to the abattoir where various processes take place such as stunning, bleeding, quartering... After this stage, various parts of the animal are transferred to the drying spot for salting, adding lard and post-salting. Furthermore, these final stages consider the office/administration phase as CO_2 emissions are also derived that are assigned to the piece of ham.

Having determined the type of LCA, the limits of the system are set (criteria that specify which of the unitary processes are part of a product system), based on the production processes of the PDO "Jamón de Teruel"/ "Paleta de Teruel".

- **Livestock and rearing phase of the animal**. Stage consisting of handling and exploiting the pig for production purposes and maximum yield and weight for subsequent use in the abattoir.
- **Abattoir.** Stage when the animal is slaughtered. During this phase, the animals are desensitised and subsequently bled. Once this process is complete, they are scalded, disinfected and skinned. Furthermore, prior to evisceration, some of the animal's tissue and organs are removed.

- **Drying areas.** Reception of raw material and start of the product manufacturing processes. Having completed all the processes (salting, washing, post-salting, maturing, etc.), the packaging and labelling process begins for subsequent commercialisation and consumption.

In this case, **Sierra Palomera** runs the drying processes, as this is the final stage of making the ham. Regarding the **functional unit** (reference unit used, from a mathematical perspective, to express the input and output data), this is the **piece of PDO "Jamón de Teruel"/ "Paleta de Teruel" with Protected Designation of Origin (PDO),** with an average weight of **9 kg.** In this way, all the unitary process flows are related to the reference flow.

7.3. DATA QUALITY REQUIREMENTS

Data quality is affected by:

- **Time.** Age and period when the data were compiled.
  The data that are compiled to quantify emissions derived from making ham/shoulder were compiled in 2020 to be as up to date as possible. In this way, the data comes from 2017, 2018 and 2019 and the ham process lasts three years, one for rearing the livestock, and two for curing the piece of ham.
- **Geography**. Geographic area for the data.
  The data correspond to the various towns in the province of Teruel, in the Autonomous Community of Aragon. In the case of data for Sierra Palomera, these correspond to Monreal del Campo, a town in the district of Jiloca, in the northeast of the province of Teruel.

- **Corresponding technology.**
  Life Cycle Analysis Software Air.e LCA Ecovent database.
- **Precision** Measurement of the variability of data values.
  The data were compiled by the companies taking part in the project to subsequently be analysed by the firm. In addition, an external company visited the organisations to check the processes and information provided by them.
- **Integrity.** Measured or estimated data.
  In the case of Teruel Ham, this report includes 100% of the parameters required to assess the LCA, having measured each data provided by the companies. However, in cases where the company did not provide any specific data, these were estimated based on the size and type of material.
- **Representation.** Qualitative assessment of how far the data reflect the real situation (geographic cover, period of time and technological cover).
  The report represents the current reality both of the product and the meat sector in general, considering the best practice and the technological level of each company taking part in the study.
- **Coherence.** Qualitative assessment of whether the study methodology is applied uniformly throughout the analysis.
  The data are applied coherently throughout the study, in accordance with the definition of the goal and scope.
- **Reproducibility.** Qualitative assessment of whether the calculation can be reproduced by an independent professional, to reproduce the results using these data and methodology.
  In this case, the methodology and the data values can be reproduced by other professionals.
- **Data sources.** Indicating where the data came from.

To draw up this LCA, different data sources have been analysed. On the one hand, the information has been compiled quantitatively to subsequently be processed. On the other hand, visits have been made to companies to check data and processes carried out and, additionally, various bibliographic sources were studied to analyse the life cycle of "Jamón de Teruel"/ "Paleta de Teruel", as well as keeping in contact with all the companies throughout the project, both by phone and by email.

Regarding the uncertainty of the information, a procedure that determines how the uncertainty of the data and suppositions evolve and how this affects the results, the personnel involved in the project used their academic training and professional experience. However, given that in a study of this type, much of the data is estimated and calculated, it is primordial to be aware of the data uncertainty, so the goal throughout the project was to reduce this uncertainty based on different types.

On the one hand, to reduce uncertainty, each piece of data was processed by multidisciplinary technicians in order to be counted, checked for errors or to see if any data was missing or any process of interest for the project.

On the other hand, to find out the real situation of the data, a wide-ranging bibliography was analysed, in addition to verifying each of the data and processes with the companies.

7.4. INVENTORY DESIGN

This inventory analysis identifies and analyses the balance of the system's material and energy, in other words, all the inputs and outputs during the ham manufacturing process, thereby including data and information compilation to be able to quantify the emissions from each activity encompassed by the system.

Data compilation for each process in the system includes:

- ✓ Inputs of energy, raw material, auxiliary inputs and other physical inputs.
- ✓ Products, joint-products and waste.
- ✓ Emissions into the air and discharge into water and soil.
- ✓ Other environmental aspects.

This quantifies the emissions from all the materials, energy consumption, fuel and transport, all contrasted with the company taking part in the study.

The data measured, calculated and estimated were compiled using various techniques and tools:

- Observation. Visits to the facilities.
- Meetings with various project coordinators.
- Meeting with business owners and technicians.
- Compilation of quantitative and qualitative data.
- Flow charts.
- Scientific research.

The units used in data compilation are:

MAGNITUDE	UNIT	SYMBOL
Volume	Litre or cubic metre	l/m^3
Mass	Gram, kilogram or ton	g/kg/t
Power	Watt	W
Length	Metre, kilometre	m/km

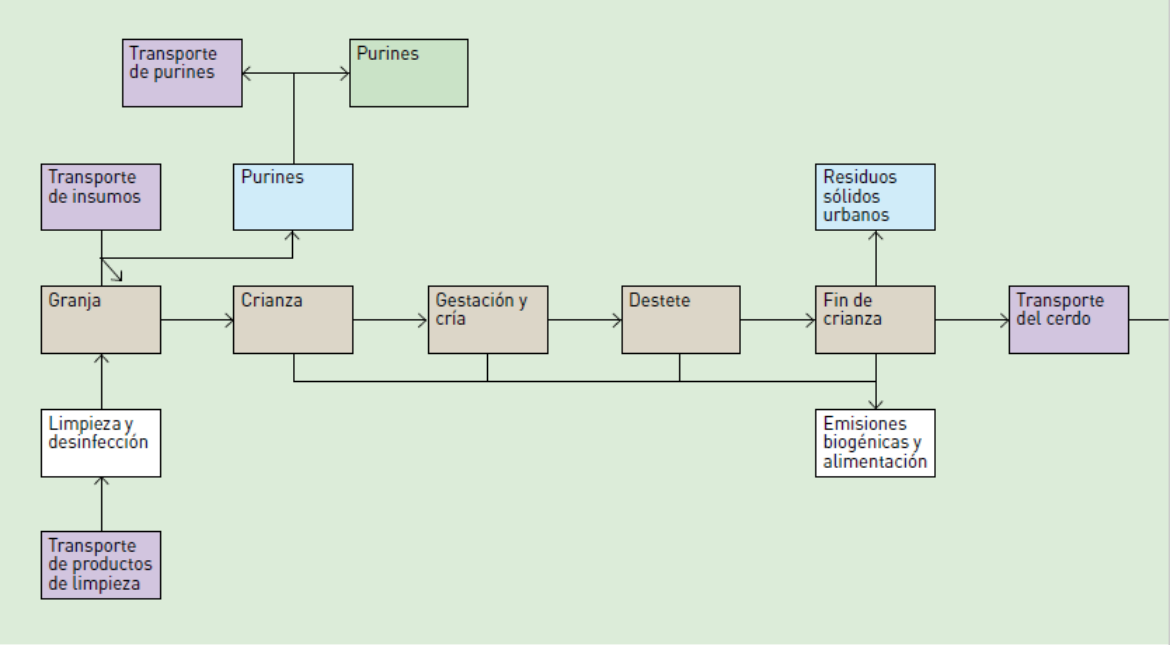
The calculation procedures contain:

- Validation of the data compiled.
- How the data relates to the unit processes.
- How the data relates to the functional unit reference flow.

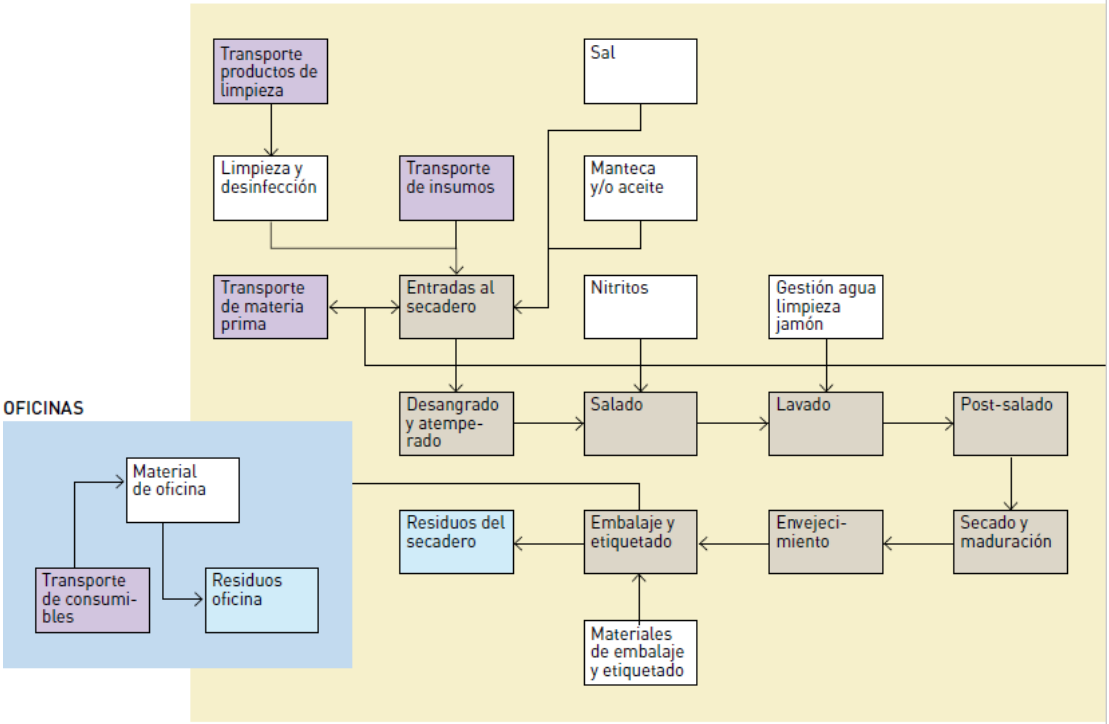
The general diagram is shown below for the processes to make a piece of PDO "Jamón de Teruel"/ "Paleta de Teruel" ham/shoulder, assigning each process a value according to the product's representation in this process.

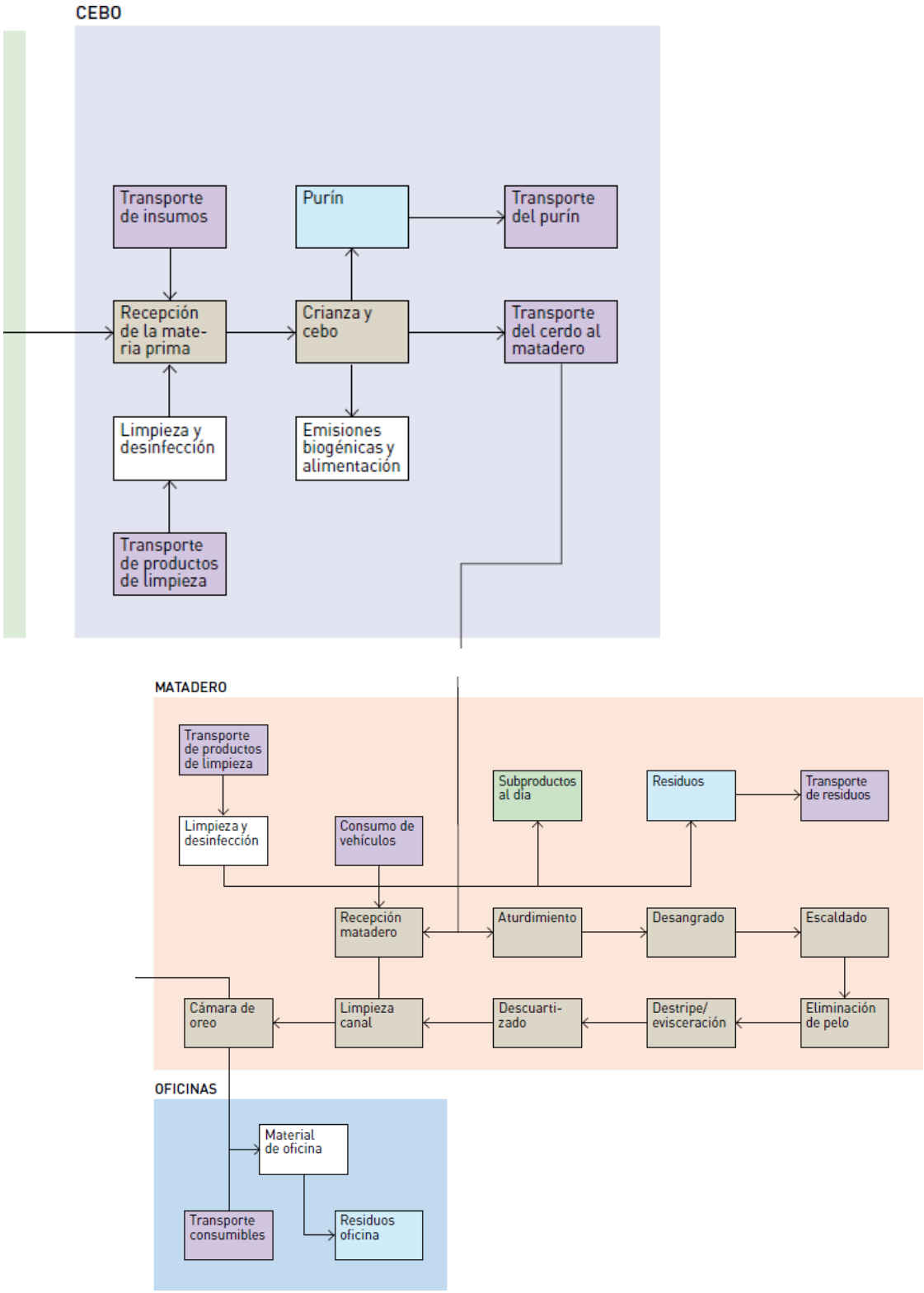
Using the previous flow chart, various processes and data are identified that are required to carry out the LCA:

NODRIZA



SECADERO




CEBO
Transporte de insumos
Purín
Transporte del purín
Recepción de la mate-ria prima
Crianza y cebo
Transporte del cerdo al matadero
Limpieza y desinfección
Emisiones biogénicas y alimentación
Transporte de productos de limpieza
MATADERO
Transporte de productos de limpieza
Subproductos al día
Residuos
Transporte de residuos
Limpieza y desinfección
Consumo de vehículos
Recepción matadero
Aturdimiento
Desangrado
Escaldado
Cámara de oreo
Limpieza canal
Descuarti-zado
Destripe/ evisceración
Eliminación de pelo
OFICINAS
Material de oficina
Transporte consumibles
Residuos oficina

At **Sierra Palomera**, the activities identified in each of the ham manufacturing process stages are:

- **Drying stage.** Period to dehydrate the product and sweat the fatty parts.
  - **Transport of consumables,** depending on the origin of the materials used during the stage.
  - **Transport of raw material.** This tallies the emissions from the total transport of ham meat (PDO).
  - **Drying facility inputs.** Quantity of salt and lard.
  - **Bleeding and tempering,** considering the characteristics of the process and energy consumption.
  - **Salting.** Type of salt used and quantity for each piece of ham. In addition, the quantity of nitrites used is tallied during this process.
  - **Washing.** Cleaning water management. Once the salting process is complete, the excess salt spread over the product will be removed. Water is consumed in this process, so the water consumption during the process and how it is managed will be considered.
  - **Post-salting.** The salt is spread inside the piece to eliminate various microbes that might appear on the product. Type of ventilation, temperature and humidity used to maintain the product. Duration of the process and electrical consumption.
  - **Drying and maturing.** Product dehydration with the aim of maintaining sufficient drying. Temperature and humidity used to maintain the product. Type of chamber used or machine room. Electrical consumption during the process.
  - **Ageing**, process where the product is held at a specific temperature and humidity for a certain time. Type of ventilation, electrical consumption and duration of the process.

- **Waste from the drying spot and its transport**. The various processes carried out during the drying stage can produce a large quantity of waste (solid waste, paper, plastic, boxes, labels, etc.). The quantity of each type of waste is tallied.
- **Packaging and labelling.** Duration of the process and type and quantity of the packaging and labelling material used for the pieces of PDO ham.
- **Cleaning and disinfection products and their transport.** Specifying the products which are used, their quantity and origin.

- **Offices**

To tally the emissions from the office stage, this quantifies the emissions derived from the use of materials, their transport and the waste produced.

However, this analysis has excluded some data due to its representation, complexity or uncertainty, and because it lies outside the companies' "control".

- Emissions related to the transport of employees to the workplace, and business trips.
- Trips by external personnel to the companies, such as the case of companies for machinery maintenance, repairs, technicians, cleaning, etc.
- Any emissions that represent less than 5% of the process's total emissions.
- Other services associated with the product such as advertising, acquisition or marketing.
- Distribution of the product to be sold.

8. ANALYSIS OF THE LIFE CYCLE INVENTORY

This section quantifies consumption of raw material and energy, plus emissions into the atmosphere, water and waste, from data collection and the flow chart.

Below, the inputs and outputs are presented for each manufacturing process for the Protected Designation of Origin "Jamón de Teruel"/ "Paleta de Teruel".

8.1. LIFE CYCLE STAGES

The life cycle stages for a piece of ham are livestock rearing, abattoir, drying area and distribution. However, the distribution stage is excluded from the LCA due to differences in data between companies. The abattoir and drying area also include the administration stage, thereby quantifying transport of materials, type, quantities used and waste generated. In addition, each stage sets out various processes that cause environmental impacts, resources consumed and substances released into the air, causing each to be analysed in this LCA.

8.1.1. DRYING AREAS

Phase in which the pieces complete their curing and desiccation in various and successive temperature, humidity and aeration conditions.

- **Transport of consumables.** Emissions are tallied from transport of raw materials and materials to make the product, in this case counting emissions from transport of salt (Sales Altava-Castellón), bands (Zaragoza), lard (Girona) and labels (Zaragoza).
- **Transport of raw material.** This counts emissions from the total transport of ham meat from Monreal del Campo.
- **Drying facility inputs.** This quantifies the total kg of pig meat that enters the drying spot, and it attributes energy consumption derived from the use of company vehicles (Volkswagen Transporter).
- **Salting.** Process in which sea salt is applied to the ham (1.85 kg/ham). It is consequently very important to keep the pieces of ham at the right temperature, so the salt is spread properly. The electrical consumption for a day in the drying spot is included in the analysis of emissions derived from the process.

- **Washing.** Washing pieces using the washing machine. The process lasts 60 seconds for each piece of ham. Each process washes 216 pieces (maximum 288). This process is attributed the corresponding water consumption.
- **Post-salting.** Stage in which a saline equilibrium is achieved through mechanical ventilation. The parts are exposed to a temperature of 2ºC, with humidity of 83%. The process lasts 100 days.
- **Drying and maturing.** Process in which the water loss takes place and when the product fragrance develops, lasting around sixty days. This process is performed by mechanical ventilation, at a temperature of 7.5ºC and humidity of 75%. The number of hams is 4,350. To quantify the emissions, the electricity consumption is considered for the sixty days of the process.
- **Ageing**. This is a process where the product is kept at a specific temperature and humidity for a certain time. This causes an increase in the proteolytic and lipolytic enzyme activity, complementing the aroma, flavour and texture of the lean meat and the fat. This uses natural ventilation, with a temperature of 3ºC in winter and 20ºC in summer. The process lasts 18 days. In addition, this process is attributed its respective electricity consumption.
- **Drying area waste.** Some waste is produced by the activities carried out when making the ham. In this case, the plastic bags generated are quantified on a monthly basis (28 bags).
- **Packaging and labelling.** Phase in which the product is packaged before being sold. This process uses direct thermal labels and bands. Each piece has a label and a band. The former weighs 5 grams and the latter weighs 10 grams.

- **Cleaning and disinfection products and their transport**. This analyses the type of product used, quantity and origin of the products. In the case of Sierra Palomera, the actual company cleans the facilities. To calculate the emissions, consumption was tallied for products used during the fourteen months of manufacturing. The products are Topaz MD 3 and Neomat I. The water consumption and quantity of wastewater were also counted in this process.

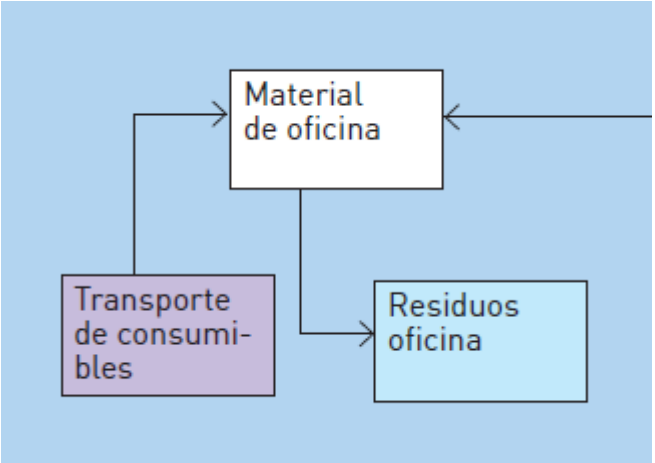
PROCESS	EMISSIONS $KgCO_2$ eq
Transport	0.01
Cleaning and disinfection	0.00
Processes in the drying spot	0.53
Waste from the drying spot	0.00
Salt	0.00
Lard and/or oil	0.00
Nitrites	0.00
Packaging and labelling materials.	0.00
Management of ham-cleaning water	0.00

PROCESS	EMISSIONS $KgCO_2$ eq
Transport of consumables	0.00
Office material	0.00
Office waste	0.00

Meat industry emissions mainly come from processes carried out in the drying spot such as quartering, bleeding, desalting, maturing, curing, etc. due to the duration of each process and the electricity it consumes.

8.1.2. OFFICES

Administration phase, constant in each process.



- **Material.** Process that quantifies how much material is used. In the office, this is universal A-A 80 g paper and two toners via a renting company.
- **Transport of consumables.** This process counts the emissions due to transporting office consumables from Zaragoza.
- **Office waste.** Using various materials during the office stage leads to paper and toner waste.

Although the CO_2 eq emissions from the office are low, it is important to consider that they also affect the environment.

CAUSES	EFFECTS
Not using recycled paper	**Resources are depleted**
Use of large quantities of paper	
Water consumption	
Energy consumption	
Use of non-renewable energy	**Atmospheric pollution**
Use of materials that contain organic solvents.	
Use of materials that contain CFC or HCFCs.	**Thinning of the ozone layer**
Use of air conditioning	
Use of felt tips and/or pens that contain harmful compounds.	**Water pollution**
Consumption of single-use products.	**Waste**
Not recycling.	

Table 1: Effects on the environment derived from the materials used in the office phase.
Source: Compiled by author.

The waste must be managed, as stated legally:

- **Regulation (CE) 1069/2009 from the European Parliament and Council, of 21 October 2009**, determining the health standards applicable to animal sub-products and derived products that are not intended for human consumption thereby repealing Regulation (CE) 1774/2002 (Regulation on animal products), determines public health and animal health standards to prevent and reduce risks to public and animal health to a minimum caused by these products and in particular, maintain food and animal chain security. Among other aspects, there are thereby checks on collection, transport, transformation, use and removal of animal sub-products, including waste of animal origin.

- **Comprehensive Waste Plan for Aragón (Plan GIRA 2018-2022),** intending to minimise the quantity of waste generated, its reuse and recycling, when it cannot be eliminated correctly.

9. LIFE CYCLE IMPACT ASSESSMENT (LCIA) AND ANALYSIS OF THE INVENTORY (LCI)

The LCA impact assessment phase intends to assess the relevance of the environmental impacts through the LCI (Life Cycle Inventory) results. In general, this process involves associating the inventory data with the specific environmental impact categories and indicators from the categories, in order to understand the impacts.

Therefore, the Life Cycle Impact Assessment (LCIA) determines the importance of each element in the inventory, putting each element into an impact category. This phase also assigns the LCI results to these impact categories (classification), and calculates the category indicators (characterisation), as mentioned in UNE-EN ISO 14044: 2006.

- **Selection of categories or impact indicators.** Phase identifying the different categories of potential impacts to which activities in each of the product stages will be subsequently assigned.
- **Classification.** LCI results are assigned to the selected impact categories. Consequently, this phase demonstrates the effects of consuming resources and CO_2 eq emissions.
- **Characterisation.** Category indicator results are calculated, identifying the characterisation factors for each substance.

- **Standardisation, grouping and weighting.** Standardisation relates the quantified magnitude for each impact category against a reference value, either on a geographic and/or time scale. As for the grouping, this classifies and catalogues the indicators. Finally, the weighting determines factors that award relative importance to the different impact categories.

CAUSES	POTENTIAL IMPACT CATEGORY	FINAL CATEGORY
Contamination of soil and water tables due to breeding livestock and cleaning facilities.	Eutrophication.	Water cycle.
Use of fossil fuels. Methane emissions.	Global warning.	Climate change.
Cleaning. Salting	Acidification.	Edaphic fertility. Crops.
Product transformation.	Formation of photochemic al oxidants.	Climate change.
Water contamination. Odours. Ammonia emission.	Thinning of the ozone layer.	Climate change.
Abattoir and drying spot.	Consumption of energy resources.	Climate change. Use of resources.
Water consumption. Ham transformation in the drying area.	Depletion of biotic resources.	Water cycle.
Odours.	Toxicity in humans.	Vegetation. Human health.
Soil use. Water consumption.	Consumption of raw material.	Vegetation. Edaphic fertility.

Table 2: Potential impact categories in the meat sector.
Source: Compiled by author.

9.1. ENVIRONMENTAL FOOTPRINT

The Environmental Footprint of a product measures its environmental impact throughout its life cycle, either directly or indirectly. The aim of this indicator is to minimise the environmental impact of all goods and services, considering the activities throughout the supply chain (extraction of raw material, production, use and waste management).

Its calculation has considered the EF 3.0 (ILCD) standardisation, to examine the emissions from each impact category as meticulously as possible, based on the impact categories.

The impact categories[1] for the Environmental Footprint are:

- **Acidification.** Consequence of atmospheric pollution by SO_2, NO_2, NH_3, NO and SO_3. This is due to altering the chemical composition and loss of the soil and water's ability to neutralise.
- **Exhausting resources.** This indicates whether the demand for the resource is greater than the offer. It analyses the water, ozone, fossil fuels and final reserves.
- **Climate change.** This adopts the values for the global warning potentials with a time frame of 100 years (GWP-100), including the carbon feedback for different substances containing carbon, carbon dioxide: and methane from various origins (fossil fuel, biogenic and use of the land).
- **Eco-toxicity.** This represents the toxic effect in the freshwater aquatic species in the water column.
- The aim of the **inorganic respiratory elements** is to evaluate the damage to human health by air emissions and under a ceiling of PM 2.5. primary and secondary in urban and rural areas.

1 Impact category. Class that represents environmental subjects of interest to which results can be assigned from the life cycle inventory analysis.

- The effects on **human health** analyse the possible impacts, carcinogenic or other, on the health of people.
- **Eutrophication** (freshwater, seawater and land). This aspect studies the effect of the nitrogen concentration as a limiting factor for NH_3 and NO_2 released into the air.
- **Formation of photochemical oxidants**. This analyses the effect after formation by reaction with sunlight in the presence of NOx and volatile organic compounds.
- **Ionising radiation.** This indicates how much this aspect affects human health.
- **Land use.** This indicates the quality of the soil after the industrial activity processes.

The environmental impact of **Sierra Palomera** is as follows:

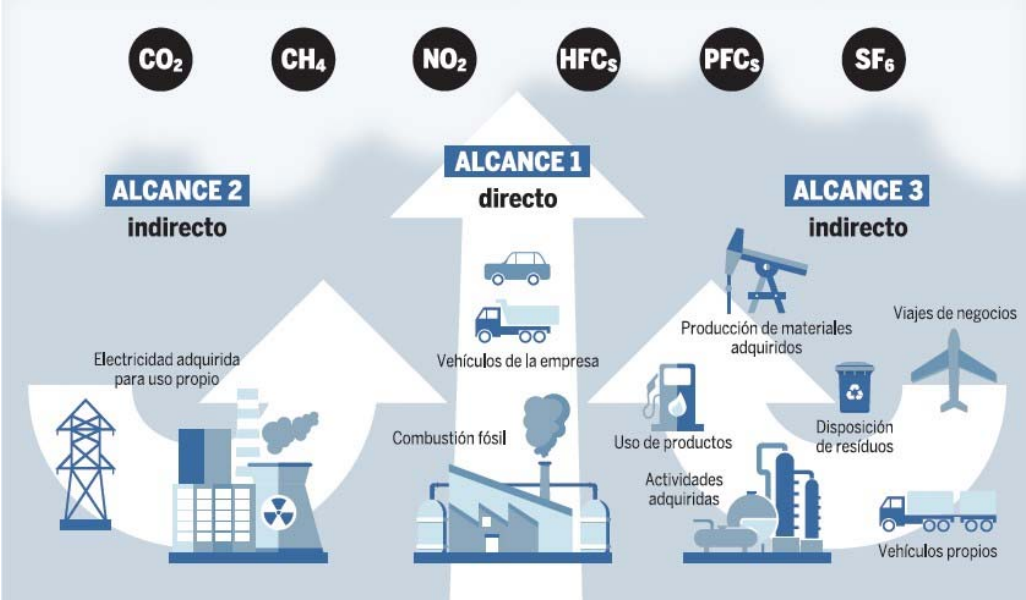
IMPACT	VALUE	UNIT
Acidification (AP)	0.0033	mol H+e
Depletion of resources (water) (WDP)	17.1572	m^3 W.ed
Thinning ozone (ODP100)	0.01034	mg CFC-11e
Depletion of resources (fossils comb) (ADPff)	9.83988	MJ
Depletion of resources (final reserve) (ADPel, ur)	0.03617	mg Sbe
Climate change (biogenic) (GW100bio)	0.06861	mg CO_2eq
Climate change (fossil fuels) (GWP100f)	598.015	g CO_2eq
Climate change (land use) (GWP100lu)	0.07558	mg CO_2eq
Climate change (GWP100)	598.015	g CO_2eq
Freshwater ecotoxicity (inorganic)	0.66475	CTUe
Freshwater ecotoxicity (metals)	1.4299	CTUe
Freshwater ecotoxicity (organic)	22.8719	CTUe
Eutrophication, freshwater (FETP)	24.9665	CTUe
Eutrophication, freshwater (FEP)	0.04878	mg Pe
Eutrophication, seawater (MEP)	435.69	mg Ne
Eutrophication, land (TEP)	0.01201	mol Ne

Formation of photochemical ozone (HOFP)	1.44094	g NMVOCe
Suspended particles (PMFP)	3.4694E-08	D.I.
Ionising radiation (human) (IRP)	82.167	Bq U235e
Human toxicity, carcinogenic effects (inorganic) (HTPcio)	2.6849E-21	CTUh
Human toxicity, carcinogenic effects (organic) (HTPcm)	4.36111E-11	CTUh
Human toxicity, carcinogenic effects (organic) (HTPco)	2.48716E-11	CTUh
Human toxicity, carcinogenic effects (HTPc)	6.84828E-11	CTUh
Human toxicity, non-carcinogenic effects (inorganic) (HTPncio)	8.86606E-10	CTUh
Human toxicity, non-carcinogenic effects (metals) (HTPncm)	7.91651E-10	CTUh
Human toxicity, non-carcinogenic effects (organic) (HTPnco)	5.20639E-09	CTUh
Human toxicity, non-carcinogenic effects (HTPnc)	6.80853E-09	CTUh
Land use (LUP)	13.2522	pt

Therefore, the greatest values are located among the impacts of ecotoxicity, climate change, land use and formation of photochemical ozone, as the result of the products used, energy consumption and transport of materials and consumables, due to the meat sector's dependency on technology.

9.2. CARBON FOOTPRINT

The Carbon footprint is one of the main indicators that measures a product's impact. It is defined as the tally of all the greenhouse gases (Gg) released directly or indirectly by a specific individual, organisation, event or product, and expressed in units of equivalent carbon dioxide (CO_2-eq), covering all activities in the life cycle.



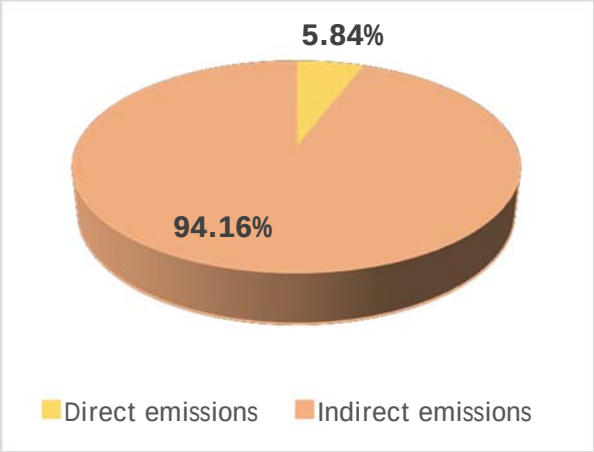
In this case, the product analysed to Calculate the Carbon Footprint was a piece of PDO Teruel ham, with an average weight of 9 kg. The greenhouse gas emissions for a piece of ham are:

548.277 gCO_2 eq/piece of ham

The ISO 14064 standard differentiates three types of emissions:

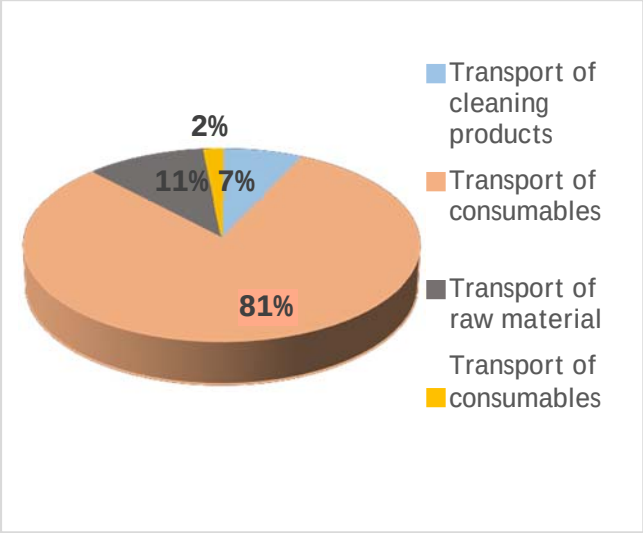
- **Direct emissions.** Emissions from the use of means of transport that are controlled or operated by the companies, plus the use of machinery in the various processes.
- **Indirect emissions.** Gg emissions caused by generating electricity to be consumed by the facilities and fuel for transport and machinery.
- **Other indirect emissions.** Emissions from the means of transport used by the employees or work trips (business trips) plus their distribution network. In this case, this type of emissions is excluded from this calculation due to the complexity of the data and they are outside the companies' operational control.

In the case of Sierra Palomera, the indirect emissions (94.16%) are higher than the direct emissions (5.84%) as a result of the energy consumption in the facilities and transport of materials.



Graph 1: Direct and indirect emissions from the Sierra Palomera drying area (%).
Source: Compiled by author.

Graph 2: Emissions derived from the use of materials during the drying phase in Sierra Palomera (%).
Source: Compiled by author.



Graph 3: Emissions derived from transport during the drying phase in Sierra Palomera (%).
Source: Compiled by author.

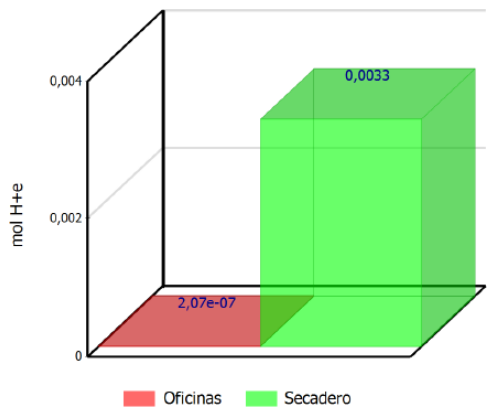
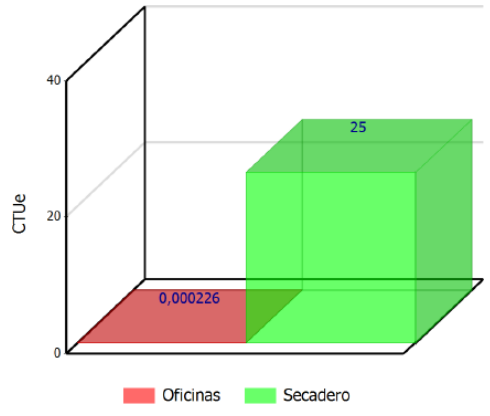
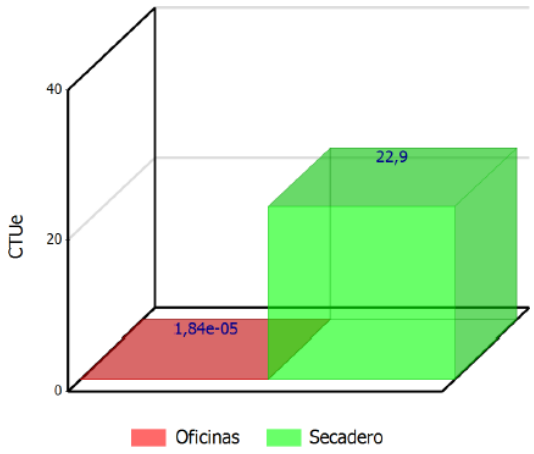
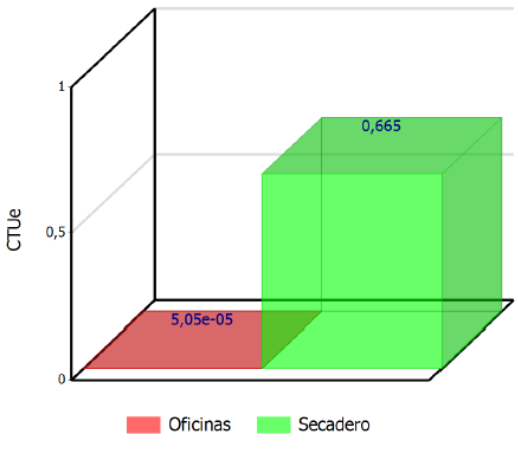
9.3. WATER FOOTPRINT

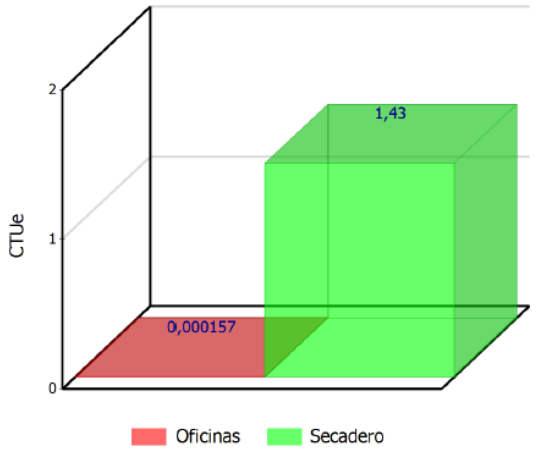
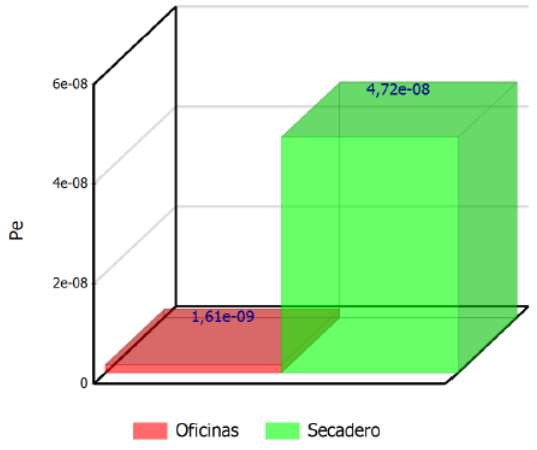
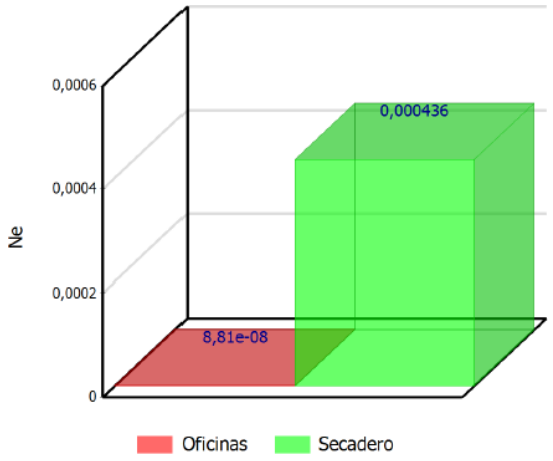
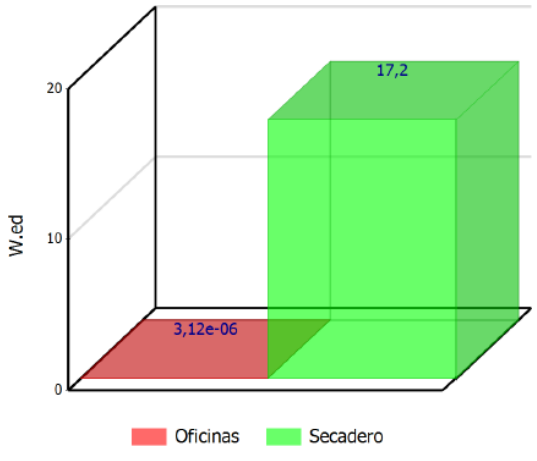
The Water Footprint quantifies the water consumption throughout the entire product cycle. In the case of Water Footprint Network (WFN), this can form part of the water footprint but alone, it is not the water footprint defined by the **ISO 14066 standard.** In this way, the water footprint obtains a more complete analysis of the product cycle.

The repercussions on the water footprint of this LCA stem from all the activities carried out in each stage of manufacturing the product, from salting, washing, maturing of the product to the packaging and labelling stage, plus cleaning the facilities.

The analysis data gives the following results for the water footprint from Sierra Palomera.

IMPACT	VALUE	UNIT
Acidification	0.0033	mol H+e
Depletion of resources (water) (WDP)	17.1572	W.ed
Freshwater ecotoxicity (inorganic)	0.6647	CTUe
Freshwater ecotoxicity (metals)	1.4299	CTUe
Freshwater ecotoxicity (organic)	22.8719	CTUe
Freshwater ecotoxicity (FETP)	24.9665	CTUed
Eutrophication, freshwater (FEP)	0.0000	Pe
Eutrophication, seawater (MEP)	0.0004	Ne

Acidification (AP)	Freshwater ecotoxicity (FETP)
	
Freshwater ecotoxicity (organic)	**Freshwater ecotoxicity (inorganic)**
	

Freshwater ecotoxicity (metals)	Eutrophication, freshwater (FEP)
	
Eutrophication, seawater (MEP)	**Depletion of resources (water) (WDP)**
	

BIBLIOGRAPHY

- Specifications for the Protected Designation of Origin "Jamón de Teruel"/ "Paleta de Teruel".
- UNE-EN ISO 14044:2006. Environmental management. Life cycle analysis, Requirements and guidelines. AENOR.
- UNE-EN ISO 14040:2006. Environmental management, Life Cycle Analysis, Principles and frame of reference.
- Methodological guide to apply the UNE-ISO 14044-1:2006 standard to develop Greenhouse gas inventories in organisations. Ihobe, Public Environmental Management Company. June 2012.
- Life cycle analysis. Industrial Organisation School. 2016.
- Zootechnical regulations to calculate the food balance of nitrogen and phosphorous. Ministry of Agriculture, Food and the Environment. 2017.
- Guide for the best techniques available in Spain for the Meat Sector. Ministry of Agriculture, Fisheries and Food. 2003.
- Environmental Study of the meat sector. Regional Development Institute.
- Recommendation from the European Commission on the use of common methods to measure and report environmental behaviour of the products and organisations over its life cycle. April 2013.

LIST OF ABBREVIATIONS AND DEFINITIONS

ABBREVIATIONS	
ADP	Abiotic Depletion Potential.
AE	Accumulated Exceedance.
CF/CFs	Characterisation factor(s).
CTUe	Comparative Toxic Units ecosystems.
CTUh	Comparative Toxic Units for human health.
EF	Environmental Footprint.
GWP	Global Warming Potential.
ILCD	International Life Cycle Data System.
LCA	Life Cycle Assessment.
LCIA	Life Cycle Impact Assessment.
NMVOC	Non-Methane Volatile Organic Compounds.
ODP	Ozone Depletion Potential.
PEF	Product Environmental Footprint.
PM	Particulate Matter.
POCP	Photochemical Ozone Creation Potential.
SOM	Soil Organic Matter.
UUID	Universally Unique Identifier.
VOC	Volatile Organic Compounds.