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Life Cycle Assessment (LCA) of Biopolymer Production

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Introduction and General Information

Within the framework of the "LIFE BIOPOL" project co-financed by the European Commission, the environmental footprint of the developed biopolymers has been evaluated through a Life Cycle Assessment study according to the following standard and reference document:
- **THE PCR TANNING CHEMICALS PRODUCT GROUP CLASSIFICATION: UN CPC 343**
- **PRODUCT ENVIRONMENTAL FOOTPRINT CATEGORY RULES (PEFCR) Leather pilot final version (23 January 2017).**

The study was carried out through Smit & Zoon's Italian subsidiary Codyeco with an external consultancy (referred to as *the Consultancy*) very experienced with LCA for the leather industry.

Scope of the study

The 5 biopolymers: BioSyn AP 72L, BioSyn CM 73L, BioSyn SC 75L, BioSyn SP 75L, BioSoft OS 761 are produced through different and subsequent chemical reactions, which are fed with intermediates derived from various biomass raw materials. Each reaction uses the product from the previous one, as well as other chemicals, energy and other resources as depicted in Figure 1.

It is important to know that the biopolymers were first produced at lab scale and then scaled up at Codyeco's industrial prototype plant at Santa Croce. The brand-new prototype plant has been specifically designed and built to equip the latest generation technologies not only capable of facilitating a new range of chemical reactions but also with special sensors monitoring the actual manufacturing parameters. All of the following data used for the LCA study have been obtained directly from the prototype plant through the installed sensors:

- Process water (l/batch)
- Thermal energy (kWh/batch)
- Electric energy (kWh/batch)

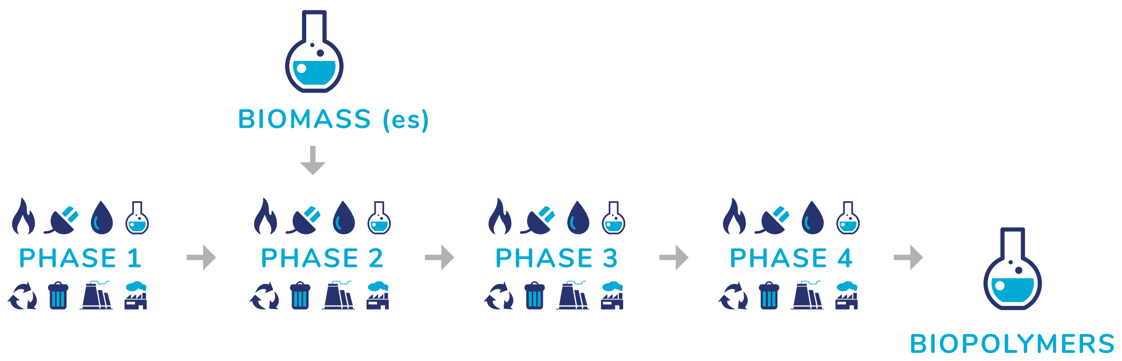

Figure 1. Schematic representation of the Bio-Polymers production process

Functional Unit and Reference Flow

Table 1 shows an example of inputs used for the LCA study based on the product BioSyn AP 72L. Similar inputs are used for the other products (BioSyn CM 73L, SC 75L, SP 75L and BioSoft OS 761) of this range.

Table 1. An example of product inputs

Product name	BioSyn AP 72L
Type of product	Polymer Based on ANIMAL PROTEIN
Destination	LEATHER MAKING
Starting from	BIOMASS 1
Reference year of the study	2018
Software tool	SIMAPRO 8.0
Database used	ECOINVENT 3.4

The unit of analysis is a Kilogram (kg) of the chemical product, as routinely measured at the production site.

System Boundaries

System boundaries are “cradle to gate” including all the environmentally relevant processes. A schematic representation of the system boundaries is shown in figure 2.

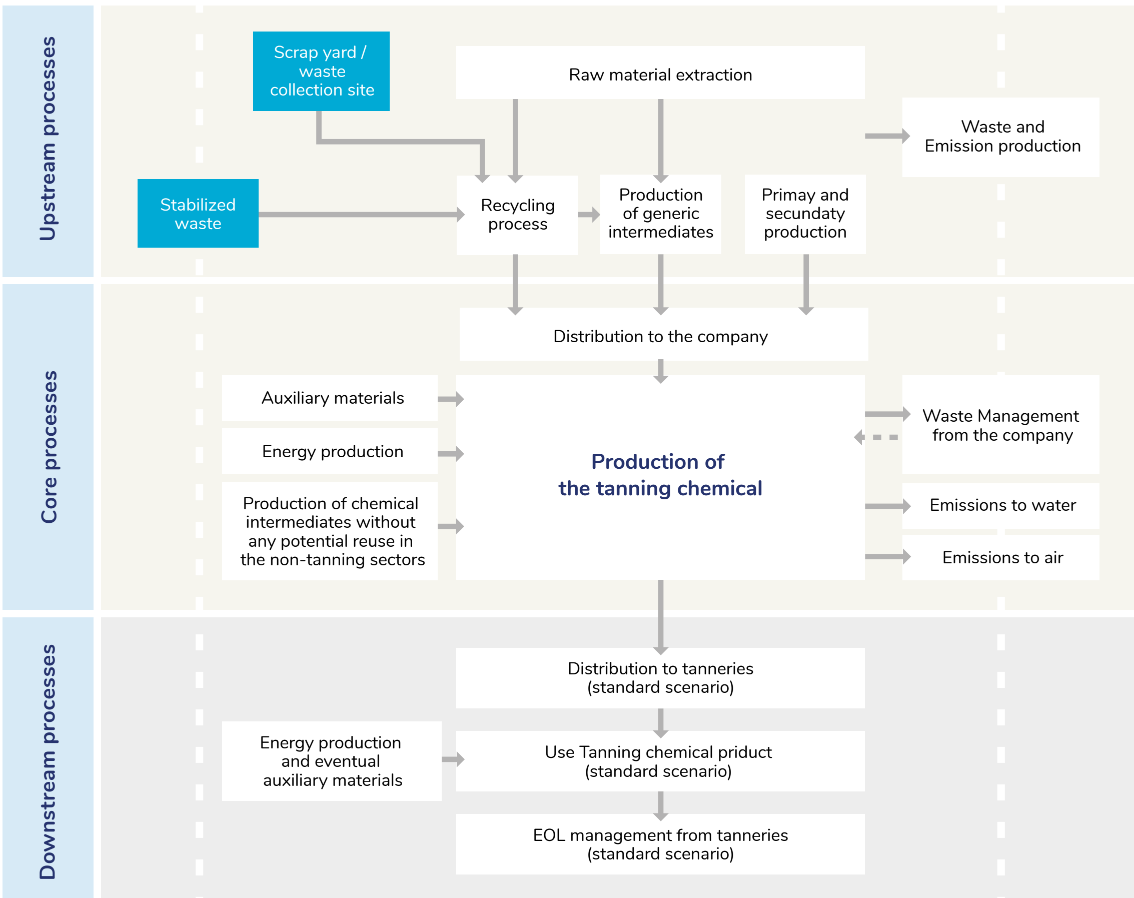

Figure 2. System boundaries used for the LCA of BIOPOL products.

Cut off Criteria, Assumptions, Impact categories

The study is based on the following significant assumptions:

- Average grid mix for electricity production of Italy applied, instead of the specific-one.
- Efficiency of transformation of primary thermal energy to process thermal energy based on estimations referring to industry averages on the current systems applied in tanneries.
- Exact composition of chemicals used in production approximated to PROXIES based on the availability on Ecoinvent.
- Inputs and outputs on water treatment have been modelled using the real data on water quality taken from the company and inputting them in a model plant created in previous sectoral work carried out by ***the Consultancy.***

The study brings in the following significant limitations:

- The limited capacity of Ecoinvent datasets to fully take into consideration the specificities of the tanning process, Especially when referring to emissions to the ecosphere (specifically referring to waste treatment).
- The limited possibilities of actually acting for impact minimization of chemicals, due to the limited knowledge of their exact composition.

The impact categories selected for the study, and for which all the results have been calculated, are the following:

Table 2. Categories selected for Life Cycle Inventory Analysis (LCIA) of the biopolymers.

Ref	Method	Impact Category	Unit
1	*CML-IA baseline V3,04*	Abiotic depletion	*kg Sb eq*
2	*CML-IA baseline V3,04*	Abiotic depletion (fossil fuels)	*MJ*
3	*CML-IA baseline V3,04*	Global warming (GWP100a)	kg CO_2 eq
4	CML-IA baseline V3,04	Ozone layer depletion (ODP)	kg CFC-11 eq
5	CML-IA baseline V3,04	Human toxicity	kg 1,4-DB eq
6	CML-IA baseline V3,04	Fresh water aquatic ecotoxicity	kg 1,4-DB eq
7	CML-IA baseline V3,04	Marine aquatic ecotoxicity	kg 1,4-DB eq
8	CML-IA baseline V3,04	Terrestrial ecotoxicity	kg 1,4-DB eq
9	CML-IA baseline V3,04	Photochemical oxidation	kg C2H4 eq
10	CML-IA Non-baseline V3,04	Acidification	kg SO2 eq
11	CML-IA baseline V3,04	Eutrophication	kg PO --- eq

Results and comparison

Complete data on Life Cycle Inventory Analysis (LCIA) of all the above 11 categories of all 5 biopolymers are available. More details are available upon request.

Results show that all retanning biopolymers (BioSyn products) score similarly (difference between data < 20%) in all of the 11 impact categories, which differ to some extent (>20% but mostly < 100% except *) from data generated on the fatliquoring biopolymer (BioSoft) on the following categories: abiotic depletion, abiotic depletion (fossil fuels), global warming (GWP100a), terrestrial ecotoxicity*, photochemical oxidation, acidification and eutrophication.

The following table lists data on the Global Warming Potential (GWP) of the 5 biopolymers in comparison with some representative existing leather chemicals used in the same leather making process:

Reference numbers have been obtained with the following procedure, that has been used also by the Technical secretariat of the Product Environmental Footprint Category Rules of the European Commission:

- Identification of the most important categories of chemicals used in the different tanning steps
- Collection of the available data with the highest possible data quality
- Identification of the average composition of the chemicals for each category
- Modelling of the "proxies" obtained with such procedure, using Simapro 8® and the latest available datasets of Ecoinvent
- Providing the results in a modular and schematic manner

Table 3. Results on the Global Warming Potential (GWP, kg CO_2 eq/kg of chemical) of the 5 biopolymers in comparison with some industrial representative chemicals.

Category	Description	Kg CO_2 eq/kg of chemical
Fatliquors and oils	fish oil (raw, sulphited, sulphated, sulphonated)	2.65
Fatliquors and oils	Synthetic fatliquors	3.19
Resins	Polyacrylic resins	1.93
Synthetic organic tanning agents	Methylene-lined condensation product of aryl sulphonic acids and hydroxyaryl sulfone	5.57
Vegetable tannins	Extracts of chestnut, myrobalan, sumac, oak	4.43
BioSyn AP 72L	Biopolymer based on animal proteins	1.28
BioSyn CM 73L	Biopolymer based on sugar cane molasses	1.27
BioSyn SC 75L	Biopolymer based on sugar beet molasses	1.22
BioSyn SP 75L	Biopolymer based on soybean proteins	1.27
BioSoft OS 761	Fatliquoring biopolymer based on sugar cane molasses	1.70

Appendices

Appendix 1: GWP of Leather Articles

The above LCA study has been extended to the evaluation of the environmental impact of all 11 categories on application of the 5 biopolymers in the leather making process of various leather types including bovine shoe upper & bags, split suede & sheep skin footwear, in which case the GWP category is expressed as kg CO_2 eq/m^2 of leather. It can be concluded that the GWP of leather articles is highly dependent on the application recipes and type of leather articles. Nevertheless a consistent decrease in GWP impact in all tested leather articles is achieved when the biopolymers are used instead of traditional (petro-chemical) leather chemicals for the same type of article.

Appendix 2: Quantity for Environmental Neutrality (QEN) and Time for Environmental Neutrality (TEN)

The concept of Quantity for Environmental Neutrality (QEN) can be expressed as a Quantity measuring the amount of material (leather) to be produced in order to compensate the environmental impacts generated for the construction and installation of the BIOPOL industrial prototype plant for the production of the biopolymers for the leather making process. It is obvious that this definition applies only in case that the production of the biopolymers has an environmental impact that is lower than the product of the same quantity (kg) that they substitute.
The LCA study has gone so far as to express the QEN taking GWP as an impact category example in "number of leather processing lots" but course it can also be expressed using other units describing the quantities of leather processed (kg, m^2).
Having calculated the QEN, considering a specific productivity (n° lots/day) of a factory or a set of factories, it is also possible to obtain the "Time for Environmental Neutrality" (TEN), for a specific product system.

Appendix 3: Data quality assessment and treatment of missing data

On data quality, what follows provides evidence on the main parameters to be taken in consideration for data Quality:

- Time related coverage
- Geographical coverage
- Technology coverage
- Completeness:
- Representativeness
- Consistency
- Reproducibility
- Sources of the data
- Uncertainty of the information

Time related coverage

All data collected refer to 2018, being it less than 12 months old at the moment of publication of the study. Since data refer to a specific process, primary data have been collected using as a reference the whole year by CODYECO Management

Geographical coverage

All primary data collected refer to the exact location where the process occurs. Datasets used for modelling have been taken as well referring to the specific location where the environmental aspect is generated. In particular:

- Thermal energy: the source is Italy, as actually occurring
- Electric energy: the dataset refers to Italy, where the electricity is actually consumed
- Chemicals: since the real production site where a chemical is produced is not often known, in order to adopt a conservative approach the "market" category of the datasets has been chosen, where possible providing the specific region. Market datasets, include average transports of that product within the geography, as well as inputs of the product itself to cover losses in trade and transport.

Technology coverage

All technologies involved in the core processes have been taken in consideration, even if the have not been described in detail due to confidentiality reasons. The overall inventory work in fact required the input of a numerous set of data, the vast majority of which is provided by CODYECO Management.

Completeness

As described above, all technologies involved in the core processes have not been described in detail, however the overall inventory work is expected to have all input and output data required.

Precision

Core process data refer to actual productions in CODYECO, with a precision level considered to be medium.

Representativeness

As said before, despite the attention put in place to obtain precise and representative primary data, during the implementation of the study several limitations related to the availability of representative datasets in Ecoinvent have been identified. The most relevant case refers to chemicals where the two most important findings of the study are represented by a lack of precise information from chemical producers and a lack of proper representation of their composition in the available datasets.

Consistency

the study methodology has been uniformly applied to the various components of the analysis.

Reproducibility

most of primary data from industrial processes and recipes have been kept confidential. SPIN 360 has never had access to commercial names of chemicals used in production, nor of the procedure to associate these chemicals to the proxies described above. These two factors contribute to a low level of reproducibility of the results of the study by an independent LCA practitioner, only based on the data included in the present Report.

Sources of the data

as explained before, declarations from the CODYECO Management and sensors directly installed on the pilot plant are the most important and relevant data Sources for primary data representing the processes under study. A smaller portion of them has been obtained through estimations or default values.

Uncertainty of the information

the most relevant assumptions of the study have been already detailed in previous paragraphs.

Allocation

100% of the processes are allocated to the Biopolymers.

More information

For more information about this whitepaper please contact info@smitzoon.com

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