LAYMAN'S REPORT

LIFEGOAST
Green Organic Agents for Sustainable Tanneries

PASUBIO GSC GROUP MEDIO CHIAMPO Università Ca'Foscari Venezia

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Green Organic Agents for Sustainable Tanneries

CONCERIA PASUBIO, GSC GROUP, MEDIO CHIAMPO
UNIVERSITÀ CA' FOSCARI DI VENEZIA

Project carried out with the contribution of the European Commission
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Project code LIFE16 ENV/IT/000416

LifeGOAST

ACKNOWLEDGEMENTS

A heartfelt thanks to those who believed in this project which aims to improve the sustainability of the tanning sector and its entire supply chain, to the European Commission for financial support, to the tanning companies I.C. Industria Conciaria, Conceria Europa, Conceria 3C, Conceria Belvedere, and Arzignanese, whose help allowed us to collect significant data for an overall impact analysis of GOAST tanning.

TABLE OF CONTENTS

Preface

When the LIFEGOAST project started four years ago, the concept of circularity of the leather supply chain was certainly less understood and felt than today. In a certain way, we anticipated some requests that would become pressing within five years. Today, in fact, environmental and economic sustainability go hand in hand, and it is no longer possible to think of production activities that do not also have environmental sustainability requirements and, better still, circularity.

The leather sector is an example of circularity that is ahead of its time, as it uses and enhances a by-product of the meat industry. Over the years, systems and technologies have been researched and developed to make the tanning process, created to make the leathers stable and resistant over time, feasible using techniques with increasingly lower environmental impact.

This is the aim of the LIFEGOAST project: researching chemical and technical formulations that have better environmental sustainability and are able to enhance the circularity of the sector.

The project partners were Conceria Pasubio, GSC Group, Medio Chiampo and the Ca' Foscari University of Venice, specifically the Department of Molecular Sciences and Nanosystems which coordinated the activities in the university context.

Over a hundred laboratory tests were carried out which resulted in five industrial tests. This highlights the commitment needed to arrive at the definition of new and more sustainable formulations and tanning techniques.

Each partner played a strategic role in this process. GSC Group specialises in chemical auxiliaries for tanning and, as project leader, coordinated the research activities and the entire process. Conceria Pasubio tanned and re-tanned the hides at a semi-industrial and industrial level, and also tested the processing products. Medio Chiampo made it possible to evaluate the impact of GOAST tanning downstream of the process, i.e. verifying the characteristics of the resulting waters and their treatment. The Ca' Foscari University of Venice worked in very close collaboration with the GSC Group laboratories and collected data to make a comparison of the two tanning systems, chrome and GOAST, also from the point of view of LCA - Life Cycle Assessment. In this way it was possible to have a complete overview of what the adoption of these new technologies on a district scale would mean. The Department of Molecular Sciences and Nanosystems then contributed to increasing the value of the project, having studied a technique for reusing the shaving waste resulting from the GOAST technology, leading to them becoming an actual resource.

The research was exciting and the results obtained gave us proof that it is possible to create an efficient tanning process, resulting in leathers with the characteristics sought after by the market and improving environmental sustainability. There are clear signs of a not-so-distant future in which nothing deriving from tanning will be wasted, but rather it will be reused in other industrial sectors, from agriculture to green building, to name but a few.

Claudio Bortolati
Director of GSC Group and coordinator of the LIFEGOAST project

LIFEGOAST in brief

LIFEGOAST belongs to the European LIFE programme which supports and promotes research and innovation on environmental and sustainability issues. It is the acronym for Green Organic Agents for Sustainable Tanneries.

The project, which began in July 2017 and ended in December 2021, aimed to demonstrate the effectiveness and benefits, on an industrial scale, of a new technology for tanning leather for the production of items for the automotive, furniture and footwear sectors, placing itself as a more sustainable alternative to the traditional chrome tanning process.

GOAST technology is based on the use of a combination of different polymer-based compounds used following a specific application protocol. This technology makes it possible to produce high quality leather without the use of chromium. The entire system aims to achieve a more sustainable tanning process in terms of global reduction of potentially dangerous substances, the containment of environmental impacts, the reduction of consumption of natural resources, especially water, and simplification of the entire tanning process. It is an innovative tanning process that can be classified as metal free. The resulting leather scraps, being free of chromium and other heavy metals, can be completely recycled

- Green Organic Agents for Sustainable Tanneries LIFEGOAST
- WHERE: Vicenza, Veneto (ITALY)
- FINANCIAL DATA:
  - Total cost: 2,367,327 Euro
  - Co-financing from the European Commission: 60% (1.374.196 euro)
- DURATION: Beginning 01/07/2017 End 31/07/2021
  (an extension was granted to 31/12/2021 due to the Covid 19 pandemic)
- THE BENEFICIARIES OF THE FUNDING:
  - Coordinator and beneficiary: GSC GROUP SPA

Other beneficiaries:
CA' FOSCARI UNIVERSITY OF VENICE, CONCERIA PASUBIO SPA, MEDIO CHIAMPO SPA

The aim of the project is to demonstrate that the implementation of LIFEGOAST technology on a semi-industrial scale is more environmentally friendly than traditional chrome tanning (TCTP).

Objectives

1. To produce high-quality, chromium-free leather goods obtained through the pilot-scale implementation of LIFEGOAST

2. To improve the quality of tannery effluents

3. To reduce dangerous substances, environmental risks and the consumption of primary resources (water)

4. The elimination/reduction of sludge containing chromium

5. The recovery/reuse of hide shavings

Results

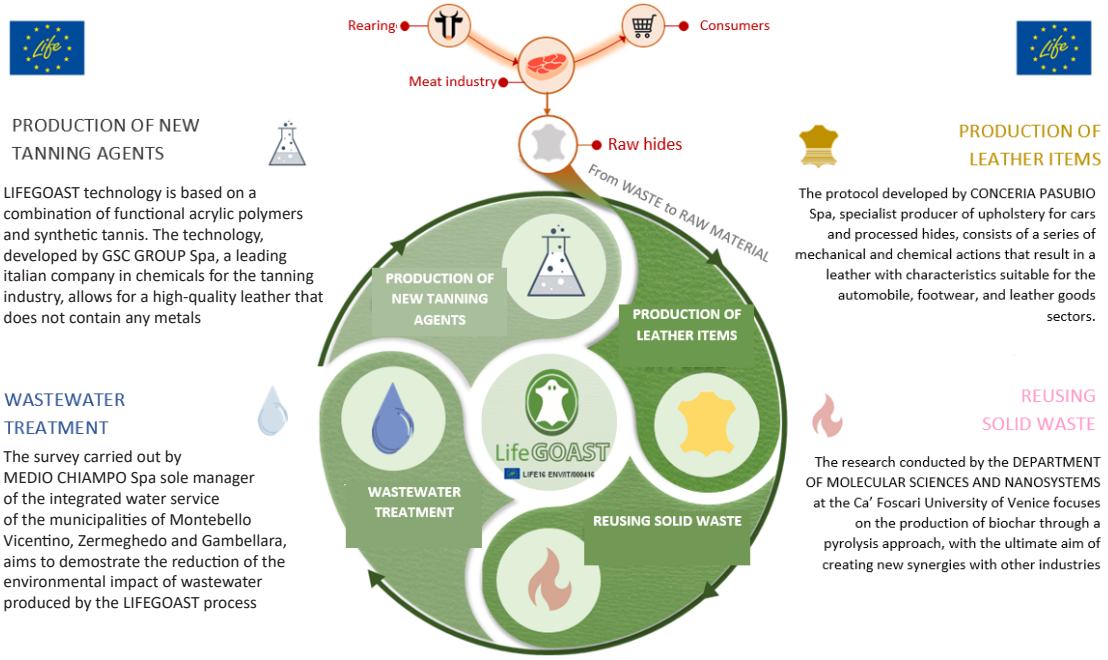
1. The LIFEGOAST team is able to produce chromium-free leather using their own technology. Semi-industrial and industrial tests are positive.

2. As regards the quality of the tannery effluents, chemicals with lower environmental impact were used and the consumption of water in industrial tests was lower.

3. No harmful chemicals were used.

4. Absence of heavy metals and therefore of chromium during processing which contributes to obtaining better sludge, free from these substances.

5. As regards the recovery of shavings, the possibility of creating biochar that can be used in various sectors has been studied.



Infographic no. 1 LIFEGOAST is a tanning technique that does not use chromium or metals, with high environmental sustainability that allows the total reuse of shavings for their use in other production sectors.

The tanning process in history

The conversion of raw hides into material with added value, stable and conservable, is a practice that has always accompanied humankind throughout history. Initially, the hides were obtained from hunted animals and then, with evolution, civilisation and the establishment of production systems, as a by-product of the food industry.

The production of leathers has always reintroduced waste material from other sectors into the production circle, increasing its value through a technical background matured from the simple artisan workshop to the most virtuous industrial reality. The tanning process is therefore to be considered a pioneer of the circular economy, where it has always supported the food and meat industry to draw on leather as its raw material [1].

The Veneto leather district

Global leather production exceeds 6.5 million tonnes per year for a turnover of 80 billion dollars [2]. Europe is the largest supplier of leather worldwide and, among the member states, Italy is in the lead, covering 65% of turnover, while globally, it represents 23% [3]. The annual production of leather in Italy stands at 116 million square metres of leather and 10,000 tonnes of sole leather for a turnover of 4.6 billion euros, figures that give it the title of leader in this sector worldwide.

By combining innovative technologies with the artisanal character of the productions, tanning represents the best of Made in Italy around the world. This Italian industry, in fact, has about 1,200 companies, mainly small and medium-sized enterprises, concentrated in the so-called production districts (Figure 2). The main district, in terms of turnover and workforce, is in Arzignano in the province of Vicenza, followed by the Tuscan district, located in the area of Santa Croce sull'Arno and Ponte a Egola (PI), and finally the Campania and Lombardy districts [1].

In the Veneto Tanning District (DVC), leather processing serves the automotive industry, the furniture sector, footwear and leather goods. In this context, Veneto alone produces 68 million square metres of leather for a turnover of 2.7 billion euros.

The DVC is made up of a dense network of companies closely interconnected with each other, including manufacturers of chemical auxiliaries, tanneries, management systems, treatment and reuse of waste generated by tanning, and companies for the design and development of machinery for the tannery. It is a true industrial supply chain, and it is a combination of chemistry and technology where the concept of sustainability has planted ever deeper roots for at least a decade.

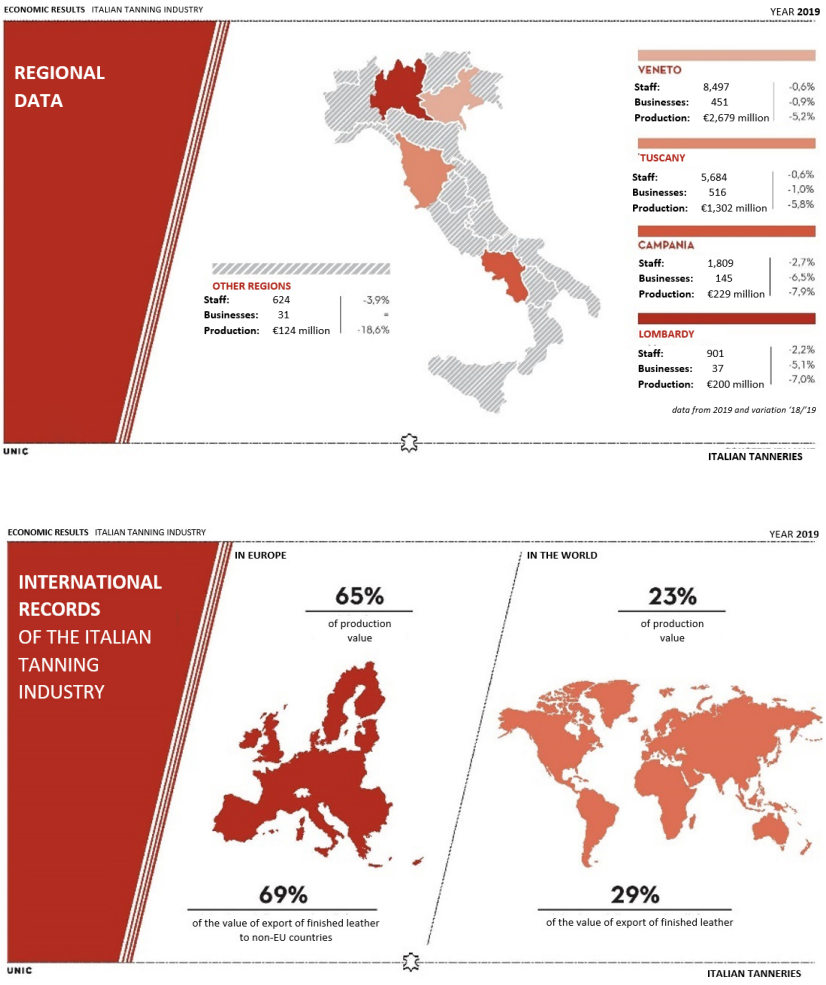


Figure 1. The international records of the Italian tanning industry in 2019 and shares on national production [4]

The search for alternative tanning processes

Over 85% of world leather production is chrome tanned and only a small proportion is produced with alternative processes [1]. The leather transformation process involves the use of various chemical substances which, over the years, has undergone a transformation as a result of specific regulations, aimed at safeguarding the environment and the end user, coming into force. Despite this, some aspects remain, which deserve to be further developed and improved from a sustainable economy perspective, even if they do not directly constitute risks.

Hence the need, throughout the production chain, to develop innovative strategies for the tanning of leathers that have sustainability and the reduction of the impact on health and the environment as their common denominator.

The LIFEGOAST LIFE16 ENV/IT/000416 project aims to implement on an industrial scale a new technology for leather tanning that is as efficient as traditional chrome tanning, but at the same time is even more environmentally friendly. The project's objective is the production of high quality leather items for the automotive, furniture and footwear sectors, free of metals, and the further improvement of the quality of wastewater from the tannery and the reduction of the consumption of primary resources such as water, through the use of innovative tanning agents.

The partners

The project involved the collaboration of experts in the tanning sector, such as GSC Group Spa as a supplier of chemical auxiliaries, Conceria Pasubio Spa as an expert in processing, and Medio Chiampo Spa as the company in charge of water treatment, with the scientific, technical and environmental support of the Department of Molecular Sciences and Nanosystems of the Ca' Foscari University of Venice (which also had the task of reusing the shaving waste). The choice of these collaborators is a manifesto of the district structure, in which we wanted to emphasise the relationship of the entire production chain in the sector.

Conceria Pasubio

"Valuable leadership is built not only by doing your job well but by doing it even better. For us, better means indicating the direction towards enhancing the circularity of leather and its environmental sustainability, giving our partners and customers the opportunity to use tanned leathers with unique green performance thanks to GOAST tanning"

Massimiliano Silvestri

Group Quality System Manager, Conceria Pasubio

Conceria Pasubio SPA is controlled by a private equity fund (PAI) and is the head of a group of companies spread out in various countries, perfectly integrated, which operates mainly in the automotive sector, supplying various materials, such as whole leathers and cut and laminated interior components [5]. Conceria Pasubio internally controls the entire production process, from the tanning of raw hides with various treatments, from chrome to vegetable tanning, for the production of *wet-blue* and *wet-white*, following the high standards imposed by the automotive sector. The production takes place in various factories located in different countries and has about 1800 employees. Its production capacity is approximately 9,000- 11,000 hides per day.

Currently, the company has embarked on an important and structured expansion process, including the acquisition of other strategic partners, with the aim of becoming a world reference point for the complete production of car interiors in the premium sector within 3–5 years.

There are already multiple customers who have chosen Pasubio as their primary supplier and they include major world players such as the VW Group (mainly Bentley, Porsche and Lamborghini), BMW and Stellantis (Maserati, Alfa, Peugeot and Opel) as well as niche OEM- *Original Equipment Manufacturers*- such as Tesla and Rolls Royce.

Currently the company has included sustainability as an important *pillar* for its development, following various international standards, such as the full application of ISO 140001 and 45001 certification. In the near future there are also plans to apply the ISO 14064 standard to all production sites to certify Greenhouse gas emissions. We intend to be completely *carbon neutral* by 2030.

GSC Group

"The LIFEGOAST project has shown us that it is possible to produce leathers of excellent quality, free from chromium and other metals, with unique sustainability and circularity characteristics. This will help improve the environmental impact of the tanning industry, making our community safer and the industries in the supply chain more advanced."

Claudio Bortolati

Director, GSC Group

GSC Group is a leading Italian company in chemical products for the tanning industry and operates in the tanning district of Arzignano, in the province of Vicenza, the world's most important tanning centre [6] .

For over forty years it has been developing innovative systems for the sector, as well as a complete range of products capable of satisfying even the most complex needs.

The GSC Group can count on a highly qualified staff of over 150 people, which includes a team of professional researchers and technicians, capable of any type of assistance, as well as a network of agents and distributors in 52 countries.

Following a policy of growth and investments, the company covers a total area of over 20,000 square metres with an annual production of 32,000 tonnes of liquids, powders and pigments. These productions are supported by green energy: GSC Group, in fact, has a solar plant of 2,000 square metres in line with an eco-friendly development concept.

The BS OHSAS 18001:2007 certification testifies to the efforts that GSC has made to meet the strict health and safety standards required by the Consolidated Safety Act of Legislative Decree 81/2008, to guarantee that the company operates by putting a central focus on the health and safety of its employees and the community.

GSC is committed to sustainability and reducing environmental impact: the production sites, in combination with the research outputs of the laboratories, work together to reduce the use of hazardous or polluting substances and to achieve careful management of waste and emissions.

GSC supports its production sites with a pool of highly qualified laboratories. The Q&A laboratory provides daily control of all raw materials and quality control on finished products. The Physical Testing laboratory performs most of the tests on the hides. The Wet-end Application Laboratory deals with tanning and re-tanning tests and the development of new products. The Finishing Application laboratory focuses on the application of finished products with a constant focus on fashion. The R&D Department focuses on developing new products to meet specific customer needs and bring innovation to the leather industry, evaluating environmentally friendly routes to produce chemical auxiliaries. There is a large focus on the development of new and more sustainable alternatives to the traditional chrome tanning system; LIFEGOAST technology is an example of this.

Medio Chiampo

"The LIFEGOAST project has given us the great opportunity to experience what could be a future development of the purification sector, building a water treatment model of the local district and gaining valuable data that will allow us to face future scenarios with greater awareness and an assurance based on knowledge"

Luigi Culpo

General Manager, Medio Chiampo

Medio Chiampo is the organisation that deals with the integrated water management (aqueduct, sewerage and purification) of the municipalities of Montebello Vicentino, Zermeghedo and Gambellara in the province of Vicenza [7]. There are 35 companies which produce waste, mainly tanneries, but also three wineries, two electroplating companies, and a foundry. The territory is particularly distinguished by the presence of industries of national importance, specialised in the processing and tanning of hides.

This meant it was necessary to have a purification centre capable of treating not only urban wastewater, but also industrial wastewater, coming mainly from tanning activities. To this end, a purification plant was built in the municipality of Montebello Vicentino in the early eighties, which was then subject to continuous technological adaptations and expansions, in relation to the quantity of production waste that has changed over time, both in qualitative and quantitative terms.

Medio Chiampo owns and manages a purification plant, an active landfill and a disused landfill, as well as a water-lifting plant. It also makes use of an internal testing laboratory, located in the municipality of Zermeghedo.

Ca' Foscari University of Venice

"The university has the dual task of broadening knowledge and improving quality of life. With the GOAST project we managed to achieve both objectives. Giving waste from the supply chain a new purpose by transforming it into a resource was only possible through a careful analysis of the waste product (shaving) and its transformation, through a pyrolysis process, into a biochar that can find different applications in terms of circular economy"

Prof. Michela Signoretto

Full Professor of Industrial Chemistry and delegate of the Rector for the Scientific area, Department of Molecular Sciences and Nanosystems, Ca' Foscari University of Venice

The Ca' Foscari University of Venice is a public institution, recognised as one of the best universities in the country that offers its students extensive study programmes in Molecular Sciences and Nanosystems, Environmental Sciences, Social, Economic and Environmental Sustainability, Foreign Languages, and Humanities [8]. Since 2007 it has received more than 100 scholarships in European and international projects, both individual and collaborative.

The teaching and research activities of the Department of Molecular Sciences and Nanosystems (DSMN) are focused on organic, industrial, inorganic, basic and applied analytical chemistry with particular attention paid to sustainability and environmental protection. The Department interacts with public and private institutions and companies, nationally and internationally.

Teaching and research courses are dedicated to the leather industry and tanning technology, making DSMN a centre of excellence in the sector, attracting great interest both at a regional and national level. In this sense, DSMN has been entrusted with several European-funded projects for the development of new environmentally sustainable technologies for the leather industry. The activity of the DSMN in this research area is documented by articles and conference proceedings. The work within the LIFEGOAST project was carried out in collaboration with the Department of Environmental Sciences, Informatics and Statistics (DAIS) and the Management Department. DSMN and DAIS are fully equipped with specialised personnel and adequate instrumentation for characterisation (e.g., NMR, GC, GC-MS, HPLC, HPLC-MS, GPC, SDS, etc.). Further activities such as life cycle analysis are provided by another UNIVE spin-off (Green Decision srl).

LIFEGOAST technology

Production of tanning agents

GOAST technology is based on the combination of suitably modified organic polymers to obtain a tanning effect on the leather. They belong to two chemical classes: acrylic polymers and tannins. For the production of these polymers, an appropriate synthetic protocol was developed at the laboratory level, leading to consistent results in the tests carried out. The *scale-up* of this protocol, which is still being implemented, has allowed us to obtain rather satisfactory results. The technology is currently *patent pending*.

It is important to highlight that, despite the different chemical nature of the tanning agent, the LIFEGOAST technology can be applied following the traditional procedure with chromium salts as a starting point, replacing the salts and adapting the process to the new reagents. The leather produced with LIFEGOAST technology has shown characteristics suitable for application in the automotive sector, which also makes it suitable, as a consequence, for other sectors such as footwear and leather goods.

Production and characterisation of leather items

The LIFEGOAST procedure consists of a series of mechanical and chemical actions performed on hides already depilated as per the standardised process on cattle for chrome tanning. The mechanical action involves the rotation of the drum and its heating, while the chemical actions consist of adding the tanning agent, various auxiliaries and adjusting the pH by adding bases (sodium bicarbonate) or weak acids (formic acid).

After the tanning phase, once the excess water has been eliminated by pressing and drying, the shaving process is carried out in order to even out the thickness of the leathers, which are then re-tanned, dyed and greased with specially developed procedures. The leathers obtained with this procedure have been subjected to numerous characterisations, which focus on the use of leather for the automotive sector. In particular, GOAST leathers showed excellent tensile strength, good elongation at break and good tear resistance, with parameters above the required values. Furthermore, they were found to have excellent resistance to heat and hydrolysis, and showed an excellent value in the gravimetric *fogging* test (approx. 2 mg with required value ≤ 3 mg), which measures the tendency of a material to release volatile substances, making it very important for use in the *automotive* sector. Finally, the characterisations on LIFEGOAST leather confirmed the *metal-free* nature with values equal to approx. 300 ppm well below 1000 ppm, which is the maximum value for classifying leather as *metal-free*.

The tanned leather obtained with the GOAST strategy is light beige in colour (figure 2) with a shrinkage temperature between 70 °C and 75 °C.

It is important to underline that the processed leathers were easily shaved with a thickness of 1.0 to 1.2 mm, ideal for the subsequent re-tanning phase.

The results obtained from the characterisations made it possible to highlight how LIFEGOAST leather possesses the characteristics suitable for the automotive sector. .

Figure 2. Leather tanned with LIFEGOAST technology. The result is a light beige leather with characteristics suitable for use in the automotive sector.

Reusing solid waste from the GOAST process

To highlight the LIFEGOAST project's attention to the sustainability of the entire leather production cycle, particular attention was also paid to the reuse of solid waste, especially that coming from the phase where the hides are shaved. The shaving waste, in fact, is an important by-product of the tanning process and consequently of the LIFEGOAST technology.

The chosen approach is that of pyrolysis, aimed at obtaining biochar, with the ultimate aim of creating new synergies with other industries by placing new materials on the market. Pyrolysis is a thermal process conducted at high temperatures in the absence of oxidising agents, which involves the decomposition of organic material with the consequent formation of a solid fraction (biochar), a condensable fraction and a gaseous fraction.

Within the LIFEGOAST project, the focus was on maximising the yield in the solid fraction (biochar) by selecting suitable operating conditions. In this context, the biochar obtained from LIFEGOAST shaving waste (Figure 3) has shown promising characteristics for its application as a soil improver, anode for lithium batteries, *replacement* of aggregates in cementitious materials and production of activated carbon.

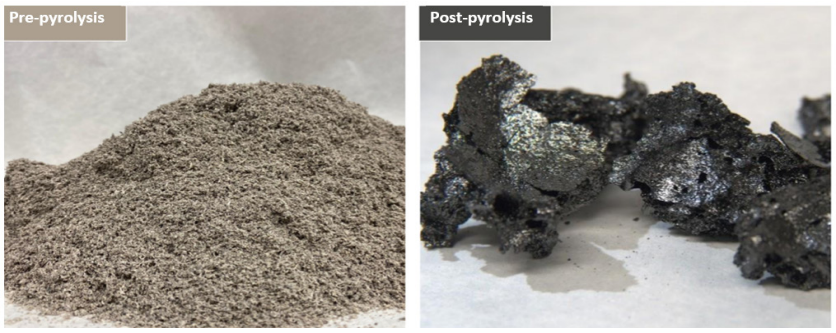


Figure 3. Biochar obtained from the pyrolysis of the shaving waste of tanned leather with LIFEGOAST technology

LCA, LCC and socio-economic impact analysis

The LCA (Life Cycle Assessment) analysis is a tool to objectively quantify the environmental performance of a product and/or service during the entire life cycle, starting from the extraction and production of raw materials up to the final disposal of products, including possible recycling of materials [9].

The research aimed to compare the environmental impact of the entire life cycle of tanned leather with the new tanning agent LIFEGOAST, with respect to the environmental impact of the entire life cycle of the TCTP process. Research has shown that removing chromium from the tanning chain reduces the environmental impact of the tanning process without compromising the quality of the leather.

At the same time, the LCC analysis is an economic evaluation methodology that allows us to identify all the costs associated with the life cycle of a product and/or service and to determine the cost over the entire life cycle. Therefore, complementary to LCA, the LCC analysis evaluated the economic sustainability of the GOAST technology, comparing it with the traditional chrome tanning, on the basis of a differential logic.

The data collection process required the contribution of all parties involved in the various stages of leather processing. Appropriate questionnaires were therefore developed for LCA and LCC analyses and an online platform was developed for their compilation.

The first step in developing the questionnaire was the definition of the functional unit (1 tonne of crust leather) and the related process steps. For each of them materials/auxiliaries, energy balances (input and output), energy costs, and fixed and variable costs have been described.

Figure 4 shows an example of the interface relating to the production of material resources.

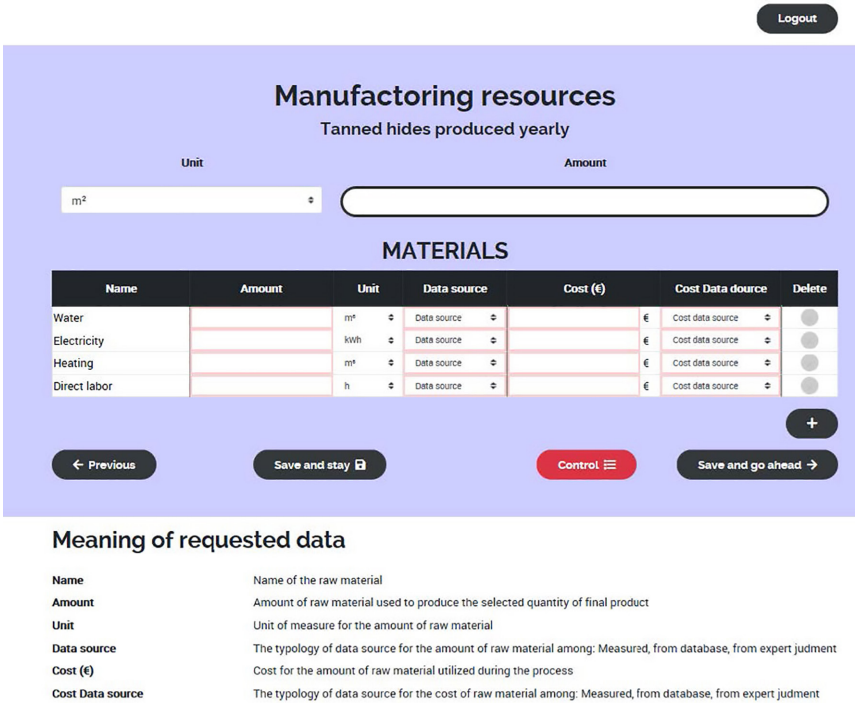


Figure 4. Interface related to the production of material resources [1]

Results of the LCA analysis

The results relating to the LCA analysis for the two tanning processes GOAST and TCTP are shown in figure 5. The graph in the figure shows the results characterised for all the impact categories envisaged by the EF Method 2.0. From the comparative analysis of the two processes, it emerges that the GOAST process is more impactful for 11 of the 19 impact categories. In particular, the greatest difference in the impact generated by the GOAST innovative process compared to the traditional TCTP one is related to the *land use* category, due to the use of vegetable tannins for the development of the innovative tanning agent. Meanwhile, the TCTP process is much more impactful for the categories related to toxicity that imply repercussions on the environment and human health, as shown by the results relating to the *ecotoxicity freshwater and cancer human health effects categories.*

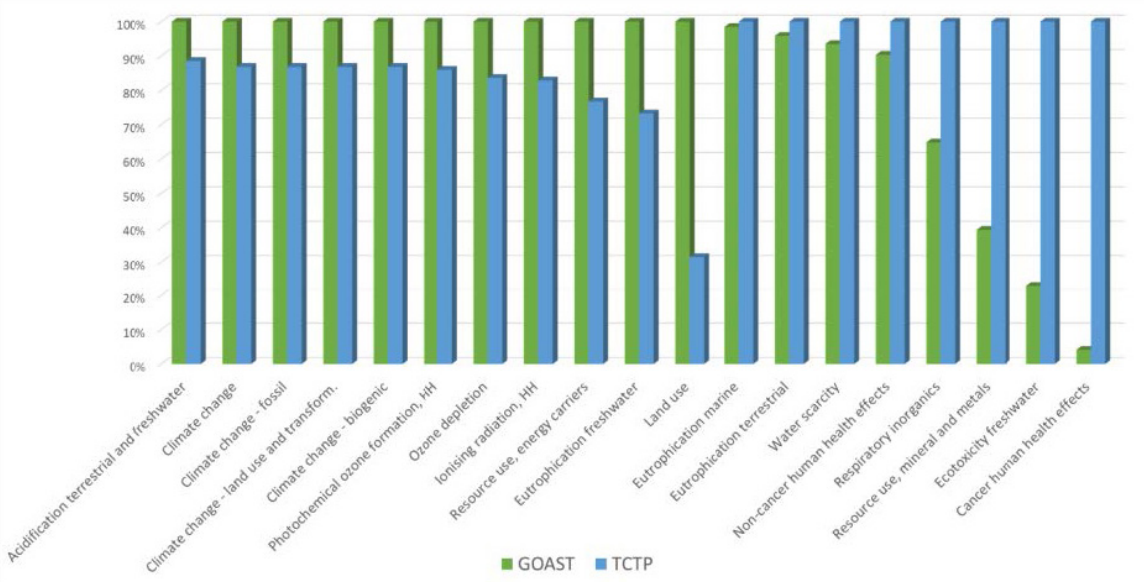


Figure 5. Comparison between the results characterised for the two tanning processes, GOAST and TCTP.

The LCA results relating to the comparison of the two processes are also presented in single scores in Figure 6. This representation, albeit linked to a greater degree of uncertainty, allows us to verify the overall impact associated with the two tanning processes and the contribution of the different impact categories.

From the graphic representation of the results it is evident that the TCTP process is more impactful than the GOAST process. This result is mainly attributed to the *cancer human health effects* impact category due to the use of chromium as a tanning agent in the TCTP process.

Other evident differences in the impacts generated by the two processes are linked to the *climate change* and *resource* use, *energy carries* indicators, for which the GOAST process is disadvantaged. This result is linked to the high quantities of tanning agent currently required for innovative tanning. In particular, these results are linked to the production of synthetic tannins.

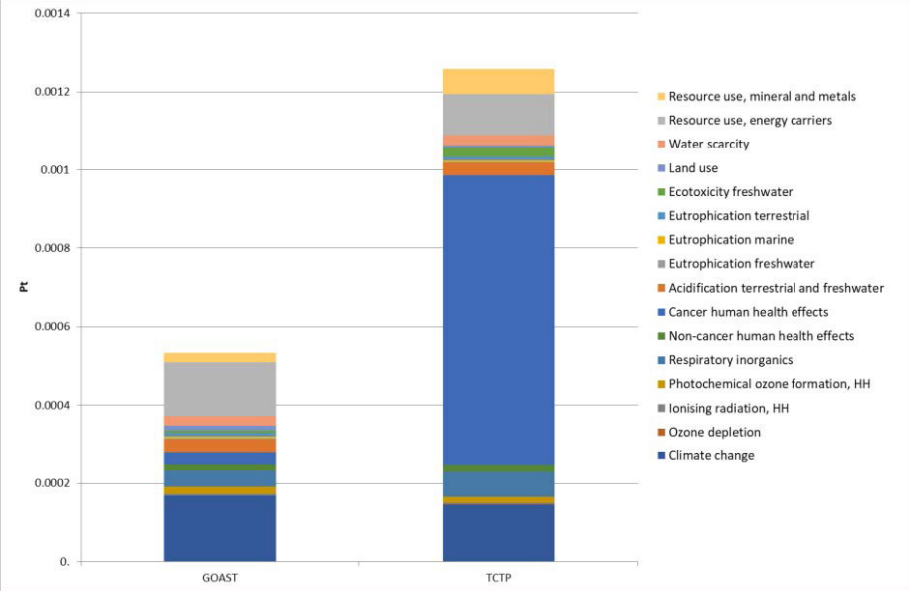


Figure 6. Comparison between the single score results for the two tanning processes, GOAST and TCTP.

Results of the LCC analysis

Regarding the LCC analysis, among the different approaches proposed by the *SETAC Europe Working Group* on LCC, it was decided to use the conventional approach which provides for the inclusion of purchase and disposal costs and arises from the point of view of a single actor, in this case the producer.

The results shown in figure 7 allow for the comparison of the cost of tanning of 1 kg of leather for the two processes- GOAST and TCTP. The graph in the figure highlights the costs associated with direct and indirect resources (*manufacturing resources*) at the various production phases: *pickling*, *tanning* and *re-tanning*. Overall, the GOAST process has high costs due to the purchase of the innovative GOAST product used as a tanning agent in the process.

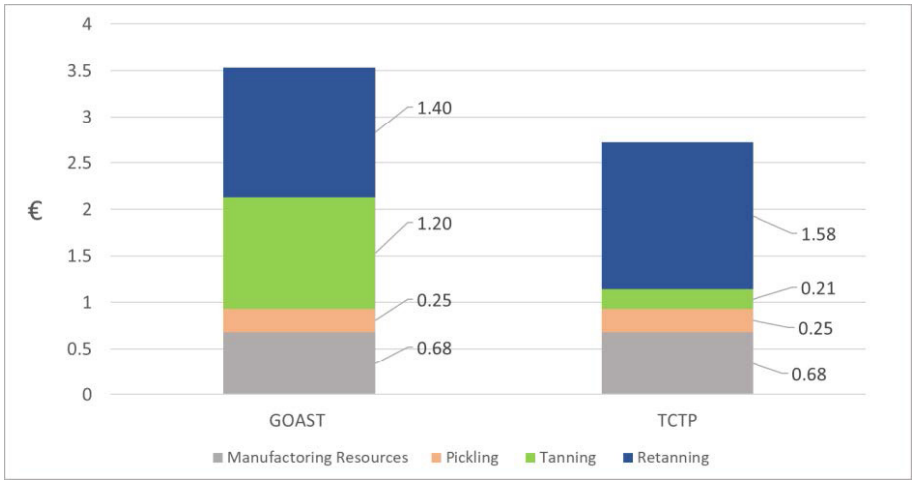


Figure 7. Comparison between the LCC results for the two tanning processes, GOAST and TCTP.

Socio-economic impact analysis

In order to assess the economic sustainability and the impact on the community deriving from the use of GOAST technology, a socio-economic analysis was also carried out. This type of analysis, in general, highlights the social/economic effect that each intervention has on the community or on the other specific entities that benefit from it.

The analysis specifically envisaged the investigation of two different interested parties (tanning companies and workers), was based on the development and administration of two questionnaires (one addressed to the workers of the tanneries and one to the companies themselves), and focussed on the organisation of work, with a dual objective: to map the state of the art in terms of competitiveness, employee well-being, and health and safety; and to explore the potential benefits of the GOAST trial in terms of workers' well-being, health and safety.

The mapped sample is represented by the companies in the Arzignano district involved in the LIFEGOAST project, namely: Pasubio, Conceria IC, Conceria Europa, Conceria 3C Lavorazioni Pelli, Conceria Belvedere.

The questionnaires were administered in 2019. The one aimed at workers was completed by 400 respondents, representing approximately 30% of the company population surveyed.
The answers provided by the workers made it possible to collect and analyse data on a strategic area of the Italian production sector, to date never recorded in these terms, and above all in relation to a new product that could improve its sustainability. In particular, the survey shows that the perceived working well-being in reference to their own company is considered at least good by 69.7% of the respondents, while 7% consider it poor and 23.3% just sufficient. Furthermore, 33.7% of workers do not know the type of tanning product and process they work with, and this is important data since it could imply training that is not entirely adequate in terms of health and safety, in line with with scientific literature on the subject.
The specific question on the trial of the new tanning technique shows that the majority of those surveyed do not know if they are using a new product in the tanning process (63.2%), and only 22.5% are aware of it, employees of the only company that started the GOAST trial. Among the latter, however, 75.6% believe that the new technology can lead to better well-being in the workplace,

Furthermore, among those who believe that the new technology can lead to better well-being in the workplace, it is interesting to highlight that 63.2% associate the perceived improvement in well-being primarily to a reduction in inhalation of toxic substances, while 19.1% refer to an improvement in the corporate climate, and finally 16.2% believe that there could be a reduction in injuries or occupational diseases.

As regards the survey conducted by means of the questionnaire addressed to companies, the owners of all five companies involved in the project responded to the *survey*. With reference to the new product for tanning, the only company that declared that it had started the GOAST trial highlighted a possible increase in competitiveness, connected to a greater eco-sustainability of the production process. In addition, the company states that it intends to make new hires by virtue of the trial, which is estimated at 5% more than the company employment figures at the time of the survey.

The well-being in the company is considered good or very good by the 5 companies, and the organisation that has declared that it is trialling the new product believes that well-being can be increased by its inclusion in the production process, thanks to the reduction of toxic substances. In conclusion, the socio-economic impact survey made it possible to identify the most recurring problems in the district, constituting a starting point for any qualitative investigations.

A first potential topic of study is represented by training on health and safety in the workplace. In this regard, it is essential that training can be provided effectively, also by using the resources allocated through the latest territorial agreement on the supplementary *welfare* of the Vicenza tanning sector, constituting a significant asset. *Welfare* is also a recognised *employee retention* tool, so continuing with structured and effective interventions in this area could contribute to solving one of the sector's problems, namely the need for qualified personnel.

Another area that could be further investigated, in the light of a first positive effect perceived and caused by trialling the GOAST project, concerns the possible reduction of skin or respiratory system diseases, related to the use of chemicals as tanning agents.

Conclusion

LIFEGOAST technology has proven to potentially be a valid alternative to the TCTP process, the optimisation of which can certainly lead to a tanning process with a lower environmental impact. It is important to highlight that, despite the different chemical nature of the tanning agent, the LIFEGOAST technology can be applied following the standard procedure of the TCTP process as a starting point, replacing the chromium salts and adapting them to new products. In addition, the greasing agents and re-tanning agents used are the same as in the TCTP process, underlining the versatility of the new technology.

The leather produced with LIFEGOAST technology has shown characteristics suitable for application in the automotive sector, a sector which requires very high performance standards when compared to others such as clothing or furniture. Therefore, this aspect makes the leather obtained also suitable for these sectors. Future work will therefore be aimed at applying the technology to the production of a wide range of leather products.

As it does not include the use of chromium and other metals in the tanning process, LIFEGOAST technology has a potentially lower environmental impact, especially as regards the treatment of wastewater and related disposal of sewage sludge, but also for the treatment of solid waste.

In this context, the pyrolysis heat treatment of the LIFEGOAST shaving powder was particularly advantageous as it allows us to obtain a carbonaceous material free of dangerous metals that does not require purification processes, so much so that it can be used as it is as a soil improver. In addition, biochar has shown modulable properties through the choice of treatment parameters and subsequent functionalisation processes, which allow its application in various fields such as catalysis, production of activated carbon or materials for green building.

The results of the LCA analysis show that the GOAST innovative process is overall more sustainable than the traditional TCTP process. In particular, the difference in the impact generated by the two processes is linked to the impact categories relating to toxicity, for which the traditional TCTP process is always at a disadvantage.

The LCA study also highlighted a criticality linked to the direct emissions of the GOAST process (in terms of kg of CO2 equivalent) compared to the TCTP process, given the greater quantity of organic chemical reagents introduced into the processing. This disadvantage is partially compensated through actions aimed at reducing GHG emissions such as the use of electricity from photovoltaic systems, a practice already explored and implemented by GSC to offset direct greenhouse gas emissions.

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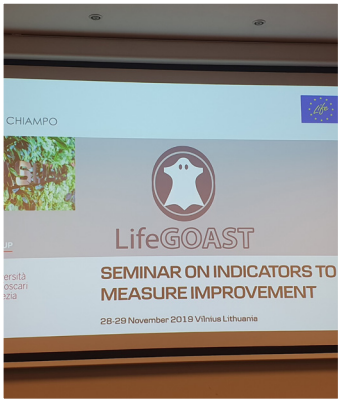
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