LIFE Project Number
LIFE10 ENV/IT/000364

FINAL Report
Covering the project activities from 01/01/2012 to 31/12/2013

Reporting Date
31/03/2014

LIFE+ PROJECT NAME or Acronym
ECOFATTING

Project Data

<table>
<thead>
<tr>
<th>Project location</th>
<th>Italia – Regione Toscana; Regione Friuli Venezia Giulia; Regione Emilia Romagna; Spagna</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project start date:</td>
<td>01/01/2012</td>
</tr>
<tr>
<td>Project end date:</td>
<td>31/12/2014</td>
</tr>
<tr>
<td>Total Project duration (in months)</td>
<td>24 months</td>
</tr>
<tr>
<td>Total budget</td>
<td>€ 1,598,700</td>
</tr>
<tr>
<td>Total eligible budget</td>
<td>€ 1,598,700</td>
</tr>
<tr>
<td>EU contribution:</td>
<td>€ 761,427</td>
</tr>
<tr>
<td>(%) of total costs</td>
<td>47.63%</td>
</tr>
<tr>
<td>(%) of eligible costs</td>
<td>47.63%</td>
</tr>
</tbody>
</table>

Beneficiary Data

<table>
<thead>
<tr>
<th>Name Beneficiary</th>
<th>Istituto di Chimica dei Composti Organo Metallici (ICCOM)-Consiglio Nazionale delle Ricerche (CNR), Via G. Moruzzi 1 56124 Pisa, Italy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact person</td>
<td>Mrs Emilia Bramanti</td>
</tr>
<tr>
<td>Postal address</td>
<td>Via G. Moruzzi 1 56124 Pisa ITALY</td>
</tr>
<tr>
<td>Visit address</td>
<td>Via G. Moruzzi 1 56124 Pisa ITALY</td>
</tr>
<tr>
<td>Telephone</td>
<td>+39-0503152552 + direct nº +39-0503152293</td>
</tr>
<tr>
<td>Fax</td>
<td>+39-0503152555</td>
</tr>
<tr>
<td>E-mail</td>
<td><a href="mailto:bramanti@pi.iccom.cnr.it">bramanti@pi.iccom.cnr.it</a></td>
</tr>
<tr>
<td>Project Website</td>
<td><a href="http://www.pi.iccom.cnr.it/ecofattting/">http://www.pi.iccom.cnr.it/ecofattting/</a></td>
</tr>
</tbody>
</table>
List of contents

1. List of abbreviations ........................................................................................................................................... 4
2. Executive Summary ............................................................................................................................................... 5
3. Introduction ........................................................................................................................................................... 11
4. Administrative part ............................................................................................................................................... 13
  4.1 Description of the management system ........................................................................................................... 13
  4.2 Evaluation of the management system ............................................................................................................. 14
5. Technical part ....................................................................................................................................................... 16
  5.1. Technical progress, per task ......................................................................................................................... 16
    5.1.1 Action 1. Study on the different fatliquoring agents currently used in the EU tanneries ........................... 16
    5.1.2 Action 2 Study on the fatliquoring agents environmental impact .......................................................... 17
    5.1.3 Action 3 Natural products demonstration and evaluation ................................................................. 19
    5.1.4 Action 4 Environmental demonstration of natural products at laboratory level .................................. 22
    5.1.5 Action 5 Fatting at a semi-industrial level by using natural products ................................................. 25
    5.1.6 Action 6. Environmental demonstration of natural products fatting at a pre-industrial level .............. 29
    5.1.7 Action 7 Environmental demonstration of hides fatted with natural products ................................. 32
    5.1.8 Action 8 Study of the demonstration about the environmental benefits from the natural products fatting process ................................................................................................................ 33
    5.1.9 Action 9. Quality assessment of leather products production ............................................................ 35
    5.1.10 Action 10. Demonstration of technical economical viability .............................................................. 36
    5.1.11 Action 11. Natural products fatting manual ......................................................................................... 38
    5.2 Dissemination actions ................................................................................................................................. 39
      5.2.1 Objectives .................................................................................................................................................. 39
      5.2.2 Dissemination: overview per activity ..................................................................................................... 41
      5.2.2.1 Action 12 Leather sample books of hides fatted with natural products ........................................ 41
      5.2.2.2 Action 13 Material preparation for workshops .................................................................................. 41
      5.2.2.3 Action 14 Diffusion material preparation ......................................................................................... 41
      5.2.2.4 Action 15 Training course for Italian tanneries .............................................................................. 42
      5.2.2.5 Action 16 Training course for Spanish tanneries ............................................................................ 42
      5.2.2.6 Action 17 Demonstration workshop in Italy ..................................................................................... 43
      5.2.2.7 Action 18 Demonstration workshop in Spain .................................................................................. 43
      5.2.2.8 Action 19 Internationals fairs and other events .............................................................................. 43
      5.2.2.9 Action 20 Digital supports for international diffusions ................................................................. 44
      5.2.2.10 Action 21 International diffusion and dissemination ................................................................. 44
      5.2.2.11 Action 22 After-LIFE Communication Plan ................................................................................ 45
    5.3 Evaluation of Project Implementation ........................................................................................................ 45
      5.4 Analysis of long-term benefits -LCA ...................................................................................................... 48
6. Comments on the financial report ...................................................................................................................... Errore. Il segnalibro non è definito.
  6.2. Accounting system ....................................................................................................................................... Errore. Il segnalibro non è definito.
  6.3. Partnership arrangements ............................................................................................................................. Errore. Il segnalibro non è definito.
  6.5 Summary of costs per action ....................................................................................................................... Errore. Il segnalibro non è definito.
7. Annexes .............................................................................................................................................................. 53
  7.1 Administrative annexes ............................................................................................................................... 53
  7.2 Technical annexes ......................................................................................................................................... 53
  7.3 Dissemination annexes ............................................................................................................................... 53
  7.3.1 Layman's report ..................................................................................................................................... 53
7.3.2 After-LIFE Communication plan ................................................................. 53
7.3.3 Other dissemination annexes ........................................................................ 53
1. List of abbreviations

SCP Sulpho Chloro Paraffin
CP Chloro Paraffin
CL Chrome Tanned Leather
GSA Gelatin Sigma type A
GSB Gelatin Sigma type B
CMS chloro Methyl Stearate
SCMS solfochloro methyl stearate
FA fatti acids
FAME fatty acid methyl ester
Cl-FAME chlorurated fatty acid methyl ester
SCI-FAME solfochlorurated fatty acid methyl ester
MeOH methanol
IPA isopropylic alchol
PEG poly ethylene glycol
TGA Thermo Gravimetric Analysis
DTG Differential Thermo Gravimetry
FTIR Fourier Trasform Infrared Sepctroscopy
COD Chemical Oxygen Demand
BOD Biological Oxygen Demand
VOC Volatile Organic Compounds
2. Executive Summary

This report represents the activities carried out under the project LIFE+ “Environmentally friendly natural products instead of chloroparaffines in the fatting phase of the tanning cycle - ECOFATTING” (LIFE10 ENV/IT/000364) over the period between 01/01/2012 and 31/12/2013.

Context

Current tanning and fatting technology utilize well established multi-step processes characterized by:

- High percentage of humid process phases, responsible of a heavy environmental impact and all current alternative technologies result in lower product quality.
- Significant use of hazardous substance in tanning such as formaldehyde and various monomers which eventually end up in wastewaters, and traces of which can also be found in the finished product.
- Fattening products are generally hardly biodegradable, and they are only partially adsorbed by derma during drum tanning. The non-absorbed product represents both an economic loss and an environmental threat because of the high COD and BOD in wastewaters.
- Use of formulations containing VOC (volatile organic compounds) or generating bioaccumulable and persistent compounds.
- An empirical and non-optimized approach to the preparation of formulations for the various process phases, resulting in slow, not efficient processes with a lot of dangerous air and water emissions.
- Low eco-sustainability due to difficulties in recycling and disposal of semifinished or finished products containing toxic metals.

Leather fattening phase is an operation which is traditionally carried out in tanneries to add flexibility to the leather after tanning and dyeing. Fattening products make up a large part of the reagents used in leather tanning, representing approximately 24% of all the products used in the industrial process. For this reason, fattening agents are one of the most important components of tanned leather, varying between 5-20% of the dry weight of the leather.

Objectives

ECOFATTING project aims to bring innovation to a specific phase in the fatting process, by developing the use of new natural products, new and more effective formulations, new technological platforms, in order to reduce the environmental impact of tanneries.

The present project aimed at demonstrating the use of an innovative technology for the fattening phase of the leather tanning process, with the goal of producing new or existing products with a significantly higher eco-sustainability profile. The specific technical goal of the project consists in the demonstration of use of a new category of products of natural origin, capable of substituting chlorosulfonated currently used in the fatting phases during the leather tanning cycle. These objectives have been fully pursued through the Actions described below.

Thanks to the intense technical/demonstrative and dissemination activities carried out during the project, a major tannery has expressed interest in the new products developed in ECOFATTING. The industrial development of the products from natural origin requires further activities (i.e: REACH registration, first-time industrial application to demonstrate the economic and environmental sustainability, market replication) and resources for which a CIP Eco-innovation project could be valuable and determining.

Results
The results of activities carried out in ECOFATTING project demonstrated the technical viability of substitution of CPs based products for fatting phase in tanning cycle with Palmkernel oil based products. The new chlorinated and sulpho-chlorinated chemicals didn't request particular application process and may be replaced instead of CPs and SCPs to produce very similar results.

More similar are the chemicals characteristics of the new products (in terms of chain length, Sulphur content and Chlorine content), more similar results are obtained on leather articles. The new chlorinated and sulpho-chlorinated chemicals can be easily used to produce a common fatliquoring agent.

Leathers obtained at laboratory, semi-industrial and pre-industrial level test have an adequate appearance, fullness and firmness, with a soft and pleasant feel and no significant differences were observed in the addition of the different fatliquoring products tested. Regarding the quality of the obtained leathers, the determinations of physical and chemical parameters in accordance with standard test have shown to be compliant with the limits required for footwear manufacture. Also, there was a reduction by 43% in the fogging test on chlorinated products (FAME with respect to CPs) and by 75% on sulpho-chlorinated products (FAME_S with respect to SCPs), which is a significant improvement by natural products compared to synthetic ones. The determination of the heavy metals (Arsenic, Cadmium and Lead) contained in the natural fatliquoring products showed the conformity with the limits established in the European Ecolabel for footwear.

**Actions and Deliverables**

**Action 1** covered the study of the existing market scenario for the different fatliquoring agents currently used in the EU tanneries order to choose the most representative existing fatliquoring agents among the different kind of chloro and chlorosulphonated paraffins. Several quite specialized products resulted to be present on the market, tailored to satisfy very specific requirements. A chlorinated paraffin with a 44% chlorine content (CLOPARIN 44F, named CP44) and a sulphochlorinated paraffin with a 30% chlorine and a 3% sulfur content (CHLOPARTEN Z, named SCP) were selected as the most effective and diffused fatliquoring agents sold on the market and therefore to be assumed as performance benchmark for the replacement products that should be considered. A third compound, a chlorinated paraffin (CLOPARIN 30F, named CP30), with a lower content of chlorine and a different chain length was selected in order to better understand the mechanism of interaction with leather components by FTIR, TGA and GC-MS and modelling studies by ICCOM-CNR, SERICHIM and ENEA.

Experimental and theoretical results showed that not covalent bonds, which include electrostatic interactions (e.g. ionic bonds between Asp- and Lys+ and hydrogen bonds), hydrophobic interactions and Van der Waals force are involved in the interactions of SCP as well as CPs more than expected. Higher content of Cl groups in CPs favorite these interactions. Sulfonylamide covalent bond between –SO2-Cl group of SCP and NH2- group of, Arg and Gln were also observed in several conditions and are fundamental for protein stabilization.

In **Action 2** INESCOP carried out the laboratory, semi-industrial and pre-industrial scale leather fatliquoring tests on wet-blue cattle hides prepared for the fatliquoring operation by means of a standard process of neutralisation, retanning and dyeing. The laboratory-scale tests were carried out in pilot drums using 1 sq. foot pieces of leather prepared for fatliquoring. Subsequently, semi-industrial scale tests were conducted on whole hides and finally pre-industrial scale test were conducted on several whole hides in a pre-industrial drum. The environmental impact of the wastewater of the different fatliquoring product families was carried out through the characterisation of the waste fatliquoring baths. The most significant parameters were assessed in accordance with international standards finding that
the polluting load of all baths was quite similar, in such a way that none of the assessed families of products stood out for a lower environmental impact.

Action 1-2 produced 5 deliverables: Fat agents (D1), “Study on the different fatliquoring agents currently used in the EU tanneries” (D2), “Interaction study “Interaction of collagen with chlorosulphonated paraffin tanning agents: Fourier Transform Infrared Spectroscopic analysis and molecular dynamics simulations” (D3), “Study of the interaction of chlorinated and sulphochlorinated paraffins with Gelatin B and chopped leather. A model for fattening in the leather tanning” (D4) and “Study on fatliquoring agents environmental impact” (D5).

Action 3 was related to the demonstration and evaluation of natural products, first performing a kilo-lab-scale screening of molecules or molecule alternative to chloroparaffins or chlorosulphonated paraffins. SERICHIM synthesized and ICCOM and ENEA evaluated four esterified vegetable fatty acid derivatives as substitute of chlorinated paraffins and solfochlorinated paraffin:
- Methyl stearate (chlorinated and solfochlorinated, CMS with 4 different Cl percentages (21, 34, 38, 44%) and SCMS, respectively).
- Methy Esters of palm oil acids (Palmkernel oil) (chlorinated and solfochlorinated, Cl-FAME and SCI-FAME)

Were also prepared and tested other products (fatty acid mixture and fatty acids methyl esters) in addition to the planned ones with the aim of collecting more information on their interaction with protein substrate and get further insight their mechanism of interaction with leather proteins. FTIR investigation showed that CMSs interact with chrome tanned leather (CL), gelatin A (GSA) and gelatin B (GSB) and this interaction is more effective in CMS at higher Cl content (CMS38 and CMS 44). This interaction can be classified as not covalent ad due to electrostatic interactions (ionic bonds between Asp- and Lys+ and hydrogen bonds), hydrophobic interactions and Van der Waals forces. It was interesting to observe that also chlorinated FAME and not chlorinated FAME, chlorinated Palmkernel Oil FAME and not chlorinated Palmkernel Oil FAME interact with gelatin, demonstrating the possibility of using not chlorinated natural compounds.

The investigation on natural products developed by SERICHIM as substitutes of solfochloroparaffins (solfochlorinated methyl stearate (SCMS), solfochlorinated Palmkernel Oil FAME) was carried out on GSA, CL and collagen.

As described in detail in the Annex of Deliverables (D1 and D2 deliverables “Natural Products”) all the solfochlorinated natural products strongly interact with GSA, collagen and CL. FTIR spectra showed new absorption suggestive of the formation of sulfonamide bonds. The application trials performed by COLORTEX (described in the following Action 4) suggest a quite good performance of the new developed chemicals compared with the standard ones, confirming the objectives of ECOFATTING.

In Action 4 we performed the environmental demonstration of natural products at laboratory level. COLORTEX and SERICHIM produced standard samples, taking chlorine and chlorosulfonated paraffins as a reference, analyzing and assessing the performances of reference samples. In particular during this action phase SERICHIM focused his activity in the production of Palm Kernel Oil based substitutes of chlorinated and sulphochlorinated paraffins at kg lab-scale. From the experience developed in Action 3 and 4 we understood that Cl content is fundamental for the chemical performance of the product and that the right comparative chemical of CP44 will be a CMS derivate containing 44 w/w% Cl substitution. However, the physical characteristics of this chemical will be different from CP44. From these results emerged that structural chemical characteristic more than physical properties are important to obtain similar application results. Good results were also obtained on leather samples using SCMS. However the best results were obtained using Cl-Palmkernel oil or Cl-FAME (as substitute of CPs) and SCI-Palmkernel oil FAME or SCI-FAME (as substitute of
SCP). For the quality characteristics of the products, these two compounds were definitely selected for the future semi-industrial and pre-industrial actions.

Once these products were selected by COLORTEX and SERICHIM, INESCOP carried out the same laboratory tests performed on the 10 reference fatliquoring product families to assess their environmental impact and their quality (laboratory scale test with bovine hides). The determination of the physical parameters of leather demonstrated that the recommended values for the manufacture of footwear were fulfilled. The results obtained show that the biodegradability of the Cl- an SCI-FAME fatliquoring bath samples (based of fatty acid methyl esters) improves by 34 - 36% with respect to the average value of the assessed fatliquoring products (1-10 product families). This action produced two deliverables “Environmental demonstration of natural products at laboratory level” (D1 and D2).

In **Action 5** COLORTEX and INESCOP performed the fatting at a semi-industrial level on different types of raw hides (from bovine, sheep and goat) by using natural products. SERICHIM studied the scale up of the pilot production of Cl-Palmkernel oil (or CI-FAME), as substitute of CPs, and SCI-Palmkernel oil (or SCI-FAME), as substitute of SCP. For the pre-industrial step SERICHIM produced 2 kg of products, which were enough for the preliminary experiments in COLORTEX and INESCOP. In their preliminary tests COLORTEX optimized a protocol (formulations) for the hide treatment. After completing the laboratory-scale tests using the natural products INESCOP carried out the same semi-industrial scale tests comparing their results with the reference values to assess the improvement of the environmental impact of the products developed (increase by 36% in the biodegradability on chlorinated products (CI-FAME respect to CP) and by 20% on sulphochlorinated products (SCI-FAME respect to SCP), always maintaining the quality of leather (international standards EN-ISO: tear strength, tensile strength, elongation at break). In all cases the assessed fatliquoring products conferred adequate softness, fullness and flexibility on the leather and the determination of these physical parameters of leather demonstrated that the recommended values for the manufacture of footwear were fulfilled. Some differences in shade were observed, which were not considered significant. Also in the “fogging test” carried out on a semi-industrial scale the results allowed us to assess the feasibility of using the new natural products in the fatliquoring of leather for car upholstery, with even better performances. Significant improvement was also observed in the biodegradation of waste coming from leather fatliquored with products from natural origin. This result supports the use of this product as an alternative to synthetic fatliquoring in the leather tanning process, since the wastes generated are biodegradable and therefore more easily to be treated. Environmental validation was performed by INESCOP and ENEA. This action has been fundamental to adjust and control the fatting process at a pre-industrial level. All the technical issues related to Action 5 are analyzed and defined in detail in the Annex of Deliverables as Action 5: Deliverables D1 and D2 “Environmental demonstration of natural products at semi-industrial level”. As scheduled, this action has been completed by 100%.

**Action 6** was related to the environmental demonstration of natural products fatting at a pre-industrial level. SERICHIM provided the selected chlorinated and sulpho-chlorinated natural products based on Palmkernel Oil at “ten kilograms” using an original know how of SERICHIM on “CONTINUOUS FLOW TECHNOLOGY”. This technology has many advantages very important in case of a future industrial production: i) high volume production with a small equipment compared to the traditional batch photochlorination reactors, ii) increase of safety in the production process due to lower hold up involved, iii) constant quality, iv) low operational cost and fixed investment required.

ICCOMCNR and ENEA set up chemical-physical tests (FTIR spectroscopy, termogravimetric analysis, TGA, GC-MS, scanning electron microscopy, SEM) to assess the quality of leather samples produced with the new method. After the laboratory scale and pre-industrial scale tests with the products selected by COLORTEX and SERICHIM, the pre-industrial scale tests
were conducted in a Spanish tannery named VERDE VELENO, S.L. located in Bétera (Valencia), by using the natural-origin products developed in the project. The results obtained in these tests were compared with the reference values so as to be able to assess the improvement of the environmental impact of the products developed, always maintaining the quality of leather. Concerning the appearance of the leather samples obtained, in all cases the assessed fatliquoring products conferred adequate softness, fullness and flexibility on the leather. Biodegradability of the Cl- and SCI-FAME fatliquoring bath samples (based of fatty acid methyl esters) improves by 41 – 48 % with respect to the average value of the assessed fatliquoring products (1-10 product families). Regarding to the quality of the obtained leathers, the determinations of physical and chemical parameters in accordance with standard test have shown to be compliant with the limits required for footwear manufacture and the determination of these physical parameters of leather demonstrated that the recommended values for the manufacture of footwear were fulfilled. Environmental validation was performed by INESCOP and ENEA. This action has been fundamental to adjust and control the fatting process at a pre-industrial level. All the technical issues related to Action 6 are analyzed and defined in detail in the Annex of Deliverables as Action 6: Deliverables D1 and D2 “Environmental demonstration of natural products at pre-industrial level”. As scheduled, this action has been completed by 100%.

In Actions 7-8 the quality assessment of the production of footwear with hides fatted with natural products carried out by INESCOP through chemical validations in accordance with accepted standards (EN, ISO, etc.), proved that ECOFATTING leathers were compliant with the criteria of the European Eco-label for footwear (Decision 2009/563/EC). Then, the suitability of these leathers was proven by manufacturing different footwear styles at INESCOP and leather-goods and leather garments at COLOTEX. The appearance of the footwear and other leather articles manufactured proved the satisfaction of the companies in manufacturing articles using hides fatted with products of natural origin. Likewise, the manufacturing process was carried out as usual and no differences were observed in the processes or in the final appearance of the models produced. All the technical issues related to Action 7&8 are analyzed and defined in detail in the Annex of Deliverables as Action 7&8: Deliverable “Environmental demonstration of hides fatted with natural products”. As scheduled, this action has been completed by 100%.

In Action 9 a quality assessment of leather products production was performed in order to to verify that hides fatted with natural products satisfy leather product quality standards. INESCOP and COLOTEX laboratories started selecting the chemical-physical validation methods (tensile strength, resistance to wear, contraction temperature, etc.) to be carried out on hides produced to manufacture leather products in Italy and Spain, in compliance with international standards (EN, ISO). All the technical issues related to Action 9 are included in the Annex of Deliverables in Action 4: Deliverables D1 and D2 “Environmental demonstration of natural products at laboratory level”, Action 5: Deliverables D1 and D2 “Environmental demonstration of natural products at semi-industrial level” and Action 6: Deliverables D1 and D2 “Environmental demonstration of natural products at pre-industrial level”. As scheduled, this action has been completed by 100%.

Action 10 was related to the demonstration of technical economic viability. This has been reported in the specific Deliverable Action 10 “DEMONSTRATION OF TECHNICAL-ECONOMICAL VIABILITY”. Therein ENEA presented the results of the assessment that hides tanned with the new natural products developed in the project comply with quality standards and are economically viable. This report is based on the collections of data and information from previous Actions, the information received from leather manufacturers and gained during project meetings and workshop. SERICHIM also successfully explored an a not foreseen activity, i.e. alternative raw material to Palm kernel oil using, as feedstock, crude acid animal fats, deriving from the fleshing step in tannery industry. SERICHIM applied is
own DeAcido technology, developed in 2008 for biodiesel, to the crude acid animal fats running some experiment in the lab scale. As a result the DeAcido process, beyond the overrun of the ethical aspects for the use of edible oils in no food industrial applications, also reduces the final price of these innovative products. This part is fundamental for the future development of the results found in ECOFATTING project. This action was developed in the last six months of the project, from July 2013 to December 2013, as scheduled.

**Action 11** was related to the preparation of a fatting manual for the use of natural products. This Manual describes the fatliquoring procedure of leathers by using the natural products optimized under the LIFE ECOFATTING project. The manual contains a step by step description of the current industrial process. It also contains first a detailed description of the conventional leather fatliquoring process and afterwards, a detailed description of the environmentally friendly natural fatliquoring process. The “Natural products fatting manual” is in Annex. As scheduled, this action has been completed by 100%.

**Action 12** is related to the preparation of a leather sample books of hides fatted with natural products. INESCOOP and COLORETX have created 20 hide sample tanned with the new and innovative natural products fatting technique, the leather sample books of hides are produced during the semi-industrial and preindustrial demonstrations and he used full grain, split calf hides and sheep skin with various finishing for different articles like shoes, leather goods, garment and upholstery.

**NETWORKING**

All leather hides and final products of ECOFATTING were produced in networking with the Life project ENV/IT/335 PODEBA, which had as main result the setting up of an eco-friendly bathing procedure with poultry deodorized with a specific procedure. This implies a big added value to ECOFATTING products and it is leaning forward the optimization of a green, sustainable tanning process. All the hides and final products were tested by GC-MS and no bad odours were found, satisfying the leather product quality standards.
3. Introduction

Environmental problem/issue addressed
Current tanning and fatting technology utilize well established multi-step processes characterized by:
- High percentage of humid process phases, responsible of a heavy environmental impact. Currently all alternative technologies result in lower product quality.
- Significant use of hazardous substance in tanning such as formaldehyde and various monomers which eventually end up in wastewaters, and traces of which can also be found in the finished product.
- Fatting products are generally hardly biodegradable, and they are only partially absorbed by derma during drum tanning. The non-absorbed product represents both an economic loss and an environmental threat because of the high COD and BOD in wastewaters.
- Use of formulations containing VOC (volatile organic compounds) or generating bioaccumulable and persistent products such as PFOA and PFOS, against which the EPA and the EU are currently taking action. This is a hot topic in the fabric treatment industry, which still lacks a technological alternative capable of meeting antisoiling and water- and oil-proofness without presenting environmental issues.
- An empirical and non-optimized approach to the preparation of formulations for the various process phases, resulting in slow, not efficient processes with a lot of dangerous air and water emissions. Such an approach also makes it harder for tanners to meet the ever-changing needs of the more and more demanding fashion and furniture markets, which also requires a faster supply chain.
- Low eco-sustainability due to difficulties in recycling and disposal of semi-finished or finished products containing toxic metals.

Outline the hypothesis demonstrated by the project
The present project aims at demonstrating the use of an innovative technology for the fatting phase of the leather tanning process, with the goal of producing new products with a significantly higher eco-sustainability profile. The specific goal of the project consists in the demonstration of use of a new category of products of natural origin, capable of substituting chlorosulfonated currently used in the fatting phases during the leather tanning cycle.

Description of the technical solution
The ECOFATTING project has the following specific technical goals:
- Demonstration of use of innovative formulations free from toxic products deriving from leather tanning;
- Substitution of chloroparaffines with eco-sustainable natural products in the fatting process
- Optimization and application of new tanning formulations specific to fatting phase, containing products derived from natural raw materials such as glucosides, biomasses, husk, vegetable oils, highly absorbed by leather.
- Study and application of intelligent and ecological products: leather treated with formulations allowing controlled release of natural biological active principles or perfumes.

Expected results and environmental benefits
The main project ECOFATTING results quantification consists in:
• Substitution (100%) of raw materials of petrochemical origin with others based on renewable sources implies a substantial change in the project’s environmental sustainability.
• Potential problems connected with bioaccumulation are ruled out by the foreseen elimination (100%) of the presence of chlorinated aliphatic molecules from the process. This, as well as the elimination (100%) of the chloro-sulfonic functional group, will increase the project’s sustainability.
• Elimination or drastic reduction of bioaccumulation will involve an increase (70%) in the biodegradability profiles of the molecules used.
• increased (30%) penetration of fat into derma, resulting in better performances of the finished product
• Fat exhaustion, i.e. less (30%) product consumption.
• Less (20%) pollutants in bath wastewaters.
• Reduction (20%) of water consumption during the tanning process
• Reduction (20%) of polluting load in tannery waste water
• Toxicity reduction of high chlorine in the tanning cycle (100%)
• Reduction of tannage waste (reduction of the waste management cost by 33%)
• Reduction of energy consumption (20%)

*Expected long-term results*
The results of the ECOFATTING project will increase in the future:
- the market of the natural products technology
- the production and market of leather with natural products and leather products (different types of leather products of different shapes, dimensions and colours) with natural products leathers

European leathers are well-known and appreciated by European leather manufacturers willing to produce high quality fashionable products. The ECOFATTING project will provide these industries with innovative and eco-friendlier leathers that will meet the European quality standards. In this sense, leather industries will be going for a type of leathers that allow for the eco-design of products, which is currently more and more demanded by European end-users. Therefore, the ECOFATTING project results will contribute to demonstrate and disseminate the innovative natural products fatting technology, thus helping to the implementation of the European Integrated Product Policy and the adoption of the Best Technologies Available (BAT) in leather companies.

In addition the ECOFATTING project results will contribute to the application of the “Green Paper on Integrated Product Policy” and of the Directive 96/64/EC regarding Integrated Pollution Prevention Control (IPPC).
4. Administrative part

4.1 Description of the management system

ECOFATTING project proceeded smoothly and all actions were completed as foreseen. During all its duration the ECOFATTING project has benefited from the close collaboration between all the beneficiaries and a close contact among them has been maintained through different media: emails, telephone, meetings, etc.

The management of the project has been carried out in compliance with what it was established in the proposal approved by the European Commission, with all partners acting in compliance with the Common Provisions and the Partnership Agreement.

The project management structure is very simple as only 5 beneficiaries are involved plus the EC and the LIFE external monitoring team. The following diagram provides information about the general management structure:

In particular the ECOFATTING beneficiaries defined the following two management structures:

- **Technical Committee:**
  - ICCOMCNR: Dr Emilia Bramanti
  - ENEA: Eng. Alice Dall’Ara
  - COLORTEX: Dr. Antonuccio Cepparone substituted after about 1 year by Dr Paola Pantani
  - INESCOP: Dr. Mercedes Roig
  - SERICHIM: Ing. Paolo Ferrario

- **Administrative Committee:**
  - ICCOMCNR: Sig.ra Manuela Cempini
  - ENEA: Eng. Ferdinando Frenquellucci retired, then substituted by Eng. Sergio Sangiorgi
  - COLORTEX: Dr. Sabrina Vastola
  - INESCOP: Dr. Julio Gutierrez
  - SERICHIM: Dr. Giuseppina Vassallo

The beneficiaries have carried out different meetings in order to organize, coordinate and develop the project. The following coordination meetings were organized:

- Coordination meetings
• Kick-off meeting, January 18th 2012, at the partner Colortex premises in Santa Croce sull’Arno (PI) - Italy.
• Progress and Coordination 6 month meeting, June 22nd 2012, at the coordinator ICCOM premises in Pisa – Italy.
• Progress and Coordination 12 month meeting, 24th January 2013, at the beneficiary Serichim premises in Torviscosa (UD) - Italy
• Progress and Coordination 18 month meeting, 13th June 2013, at the beneficiary INESCOP premises in Elda-Alicante - Spain
• Final 24 month meeting, 11th December 2013, at the coordinator ICCOM premises in Pisa – Italy.
  ➢ Monitoring meetings with LIFE’s External Assistance Team:
  • LIFE beneficiaries Progress and Coordination 6 month meeting, June 22th June 2012: Mr. Ludovico Susani.
  • Monitoring visit June 28th June 2013 at ICCOM-CNR in Pisa: Mr. Ludovico Susani.
  ➢ Desk Officer Visit:
  • Financial and technical desk officer visit, October 15th 2013, at the partner Colortex premises in Santa Croce sull’Arno (PI) – Italy

In addition many meetings between some partners were organised in order to plan and monitor the project technical activities.

4.2 Evaluation of the management system

The ECOFATTING management process needed daily work to maintain a permanent flow of action with the aim of achieving the objectives set. The specific management activities carried out were:
  ➢ Preparation of the Partnership Agreement and relative Addendum (sent with the Inception Report)
  ➢ Organisation of Coordination meetings
  ➢ Organisation of different meetings between some beneficiaries in order to plan and monitor the project technical activities
  ➢ Continuous contact between all project beneficiaries for monitoring project activities
  ➢ Preparation of material for meetings and dissemination events.
  ➢ General actions and activities for the coordination of the project.
  ➢ Management of the financial aspects of the project.
  ➢ Monthly reports to the LIFE external team monitor on the evolution of the project.

As shown in the previous diagram reported above, the ECOFATTING Beneficiaries added values were:
  ➢ ICCOMCNR, project coordinator, specialist and responsible of chemical and environmental analyses
  ➢ ENEA, expert in the leather sector responsible of environmental analyses
  ➢ SERICHIM, expert in chemical compounds responsible of the natural product production
  ➢ COLORTEX, expert in the tanning sector responsible for the tanning trials and production of leather products
  ➢ INESCOP, expert in the leather sector responsible for the laboratory tests, tanning trials and production of leather products in Spain.

During all the project lifetime, the 4 beneficiaries associated, ENEA, Colortex, Serichim and INESCOP participated in project management activities, keeping in smooth contact with the project coordinator. In this sense, they prepared and attended the project management meetings and collaborated with the project coordinator (ICCOMCNR) in the preparation of
the Inception Report, of the Progress Report and of this Final Report, as set out in the project proposal.
During all the project lifetime, monitoring tasks have been carried out for each action, in particular:

- ICCOMCNR, as project coordinator, had continuous contact with all project beneficiaries for monitoring project activities
- ICCOMCNR, as project coordinator, prepared and sent a monthly indication of operative activities to be done to all the beneficiaries
- ICCOMCNR, as project coordinator, every month sent a report to the monitor of LIFE’s External Assistance Team on the progress of the project, which allowed him to follow-up of the ECOFATTING project.
5. Technical part

5.1. Technical progress, per task

5.1.1 Action 1. Study on the different fatliquoring agents currently used in the EU tanneries

Action 1 started on 01-01-2012 as scheduled in the project and it has been completed on 30-09-2012. This first activity has covered the study of the existing market scenario for the above mentioned products and this in order to choose the most representative existing fatliquoring agents among the different kind of chloro and chlorosulphonated paraffins. Moreover the review was intended to assess the marked size, in order to verify how new uses of selected raw materials can influence their market structure.

Several quite specialized products resulted to be present on the market, tailored to satisfy very specific requirements. In this population some leading representatives had to be selected. Following discussion with COLORTEX and based on their industrial knowledge a chlorinated paraffin with a 44% chlorine content (corresponding to commercially available CLOPARIN 44F, quantity: 2,00 kg - March 2012; chlorine content % m/m 44,5-46,5, chain length C14-C17, named CP44) and a sulphochlorinated paraffin with a 30 % chlorine and a 3 % sulfur content (corresponding to commercially available CHLOPARTEN Z, quantity: 2,00 kg - March 2012, chlorine content % m/m 29-31, named SCP) were selected as the most effective and diffused fatliquoring agents sold on the market and therefore to be assumed as performance benchmark for the replacement products that should be considered (for details see ANNEX of Deliverables). A third compound, a chlorinated paraffin (CLOPARIN 30F (Quantity: 2,00 kg - March 2012; chlorine content % m/m 30, chain length C18), named CP30, with a lower content of chlorine and a different chain length was selected, sent to ICCOM CNR and characterized in order to better understand the mechanism of interaction with leather components by FTIR, TGA and GC-MS by ICCOM-CNR, SERICHIM and ENEA.

Study of the interaction of CP30, CP44 and SCP with leather components.
The study of the interaction of CP30, CP44 and SCP with leather components was performed by ICCOMCNR nd ENEA following different approaches: i) FTIR spectroscopic analysis; ii) termogravimetric analysis (TGA); iii) modelling computational study. All details related to this part are reported in the Inception Report, in the technical annex to the Inception Report and in the current Annex of Deliverables.

Theoretical investigation of the interactions between Collagen Microfibrils and SCP.
All solvent species are found in the first solvation shell around the bundles where they are in direct contact with the protein residues. The bundles inflate due to water activity but the fibril conformation is maintained due to the presence of the cross-linking agents. Water molecules surround the bundles but are also found between the helices. SCP molecules are located prevalently between the CMSs (Figure 1) and in the terminus regions of the chains and their oxygen atoms interact with the amine groups of ARG and GLN residues.

Figure 1. Model of collagen/SCP interaction.
The main output of this action was the evidence of the formation of a chemical bond between reactive sulphochloride groups and basic groups existing on collagen.

In conclusion, all these results showed that not covalent bonds, which include electrostatic interactions (e.g. ionic bonds between Asp- and Lys+ and hydrogen bonds), hydrophobic interactions and Van der Waals forces are involved in the interactions of SCP as well as CPs more than expected. Higher content of Cl groups in CPs favor these interactions. Sulfonamide covalent bond between –SO2-Cl group of SCP and NH2- group of, Arg and Glu were also observed in several conditions and are fundamental for protein stabilization. From simulation studies we found that SCP molecules are located prevalently between the CMSs and in the terminus regions of the chains and their oxygen atoms interact with the amine groups of ARG and GLN residues.

The results of this study allowed us also to select acyl chloride group as the chemical functional group that could give the same performance of sulphochlorine group in leather application. Acyl chlorides and chlorinated acyl chlorides can be derived from fatty acids, which are the main oleochemical raw materials.

All technical details related to this Action are reported in the following Action 1-2 deliverables: Fat agents (D1), “Study on the different fatliquoring agents currently used in the EU tanneries” (D2), “Interaction study “Interaction of collagen with chlorosulphonated paraffin tanning agents: Fourier Transform Infrared Spectroscopic analysis and molecular dynamics simulations” (D3), “Study of the interaction of chlorinated and sulphochlorinated paraffins with Gelatin B and chopped leather. A model for fattening in the leather tanning” (D4).

In conclusion, all these results showed that not covalent bonds, which include electrostatic interactions (e.g. ionic bonds between Asp- and Lys+ and hydrogen bonds), hydrophobic interactions and Van der Waals force are involved in the interactions of SCP as well as CPs more than expected. Higher content of Cl groups in CPs favor these interactions. Sulfonamide covalent bond between –SO2-Cl group of SCP and NH2- group of, Arg and Glu were also observed in several conditions and are fundamental for protein stabilization. From simulation studies we found that SCP molecules are located prevalently between the CMSs and in the terminus regions of the chains and their oxygen atoms interact with the amine groups of ARG and GLN residues.

5.1.2 Action 2 Study on the fatliquoring agents environmental impact

During the first stage of the LIFE ECOfATTING project, the fatliquoring product families that are most widely used by European tanneries were assessed by INESCOP from the point of view of their environmental performance, setting the parameters to be analysed, as much in fatliquoring products and the wastewater produced in the fatliquoring stage, as in the leather obtained (physical, chemical and organoleptic parameters).

The results obtained will be used as a standard against which the improvement of the environmental impact of the natural fats developed will be compared. For this, the fatliquoring product families to be assessed were firstly selected, as shown in Table 1.

<table>
<thead>
<tr>
<th>1</th>
<th>Sulphated olein</th>
<th>6</th>
<th>Sulphated ester</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Sulphonated olein</td>
<td>7</td>
<td>Phosphoric ester</td>
</tr>
<tr>
<td>3</td>
<td>Sulphited olein</td>
<td>8</td>
<td>Sulphochlorinated paraffin</td>
</tr>
<tr>
<td>4</td>
<td>Sulphited fish oil</td>
<td>9</td>
<td>Synthetic oils</td>
</tr>
<tr>
<td>5</td>
<td>Sulphated lecithin</td>
<td>10</td>
<td>Fatliquoring polymer</td>
</tr>
</tbody>
</table>

Table 1. Fatliquoring product families evaluated
Then, the laboratory, semi-industrial and pre-industrial scale leather fatliquoring tests were conducted at INESCOP-U.T. Vall d’Uixó facilities using the selected products. These tests were carried out on wet-blue cattle hides that had been prepared for the fatliquoring operation by means of a standard process of neutralisation, retanning and dyeing. The laboratory-scale tests were carried out in pilot drums using 1 sq. foot pieces of leather prepared for fatliquoring. Subsequently, semi-industrial scale tests were conducted on whole hides and finally pre-industrial scale test were conducted on several whole hides in a pre-industrial drum (Figure 2).

Figure 2. Laboratory, semi-industrial and pre-industrial scale fatliquoring tests (INESCOP-UT Vall d’Uixó facilities)

The fatliquoring process performed on neutralised, retanned and dyed leather is shown in Table 2:

Table 2. Working procedure for leather fatliquoring

<table>
<thead>
<tr>
<th>PRODUCT/PROCESS</th>
<th>% by wet-blue weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water (45-50 °C)</td>
<td>500 %</td>
</tr>
<tr>
<td>Fatliquoring product</td>
<td>8 % (*)</td>
</tr>
<tr>
<td></td>
<td>Rotate for 90 min</td>
</tr>
<tr>
<td>Formic acid (1:10 dilution)</td>
<td>3%</td>
</tr>
<tr>
<td></td>
<td>Rotate for 20 min</td>
</tr>
<tr>
<td></td>
<td>Wash, drain drum, take bath sample and remove leather</td>
</tr>
<tr>
<td></td>
<td>Air dry</td>
</tr>
</tbody>
</table>

(*) In commercial products, greases are mixed with water or emulsifiers with an active ingredient concentration of 65-80%. For this reason, the percentage of the commercial product added is recalculated for each fatliquoring product so as to ensure the addition of the same amount of grease to all leathers.

Once this operation was completed, a sample of the waste fatliquoring bath and a sample of one of the obtained leathers were taken for the determination of the selected physical parameters. Concerning the appearance of the leather samples obtained, in all cases the assessed fatliquoring products conferred adequate softness, fullness and flexibility on the leather (Figure 3). Some differences in shade were observed, which were not considered significant.
The environmental impact of the wastewater of the different fatliquoring product families assessed was carried out through the characterisation of the waste fatliquoring baths. The most significant parameters were assessed in accordance with international standards. Table 3 shows the results obtained for the different fatliquoring product families studied (semi-industrial scale tests), as well as the average reference values to facilitate the comparison of results:

<table>
<thead>
<tr>
<th>Reference</th>
<th>pH</th>
<th>Conductivity (µs/cm)</th>
<th>COD (mg O₂/l)</th>
<th>BOD₅ (mg O₂/l)</th>
<th>Biodegradability (BOD₅ / COD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Sulphated olein</td>
<td>3.9</td>
<td>3,000</td>
<td>13,800</td>
<td>5,106</td>
<td>0.37</td>
</tr>
<tr>
<td>2 Sulphonated olein</td>
<td>3.9</td>
<td>3,000</td>
<td>15,000</td>
<td>8,850</td>
<td>0.59</td>
</tr>
<tr>
<td>3 Sulphited olein</td>
<td>3.7</td>
<td>1,900</td>
<td>17,800</td>
<td>8,366</td>
<td>0.47</td>
</tr>
<tr>
<td>4 Sulphited fish oil</td>
<td>3.8</td>
<td>2,100</td>
<td>18,300</td>
<td>8,052</td>
<td>0.44</td>
</tr>
<tr>
<td>5 Sulphated lecithin</td>
<td>3.8</td>
<td>2,200</td>
<td>17,400</td>
<td>6,960</td>
<td>0.40</td>
</tr>
<tr>
<td>6 Sulphated ester</td>
<td>3.5</td>
<td>2,500</td>
<td>15,900</td>
<td>7,632</td>
<td>0.48</td>
</tr>
<tr>
<td>7 Phosphoric ester</td>
<td>3.6</td>
<td>2,100</td>
<td>14,700</td>
<td>3,087</td>
<td>0.21</td>
</tr>
<tr>
<td>8 Sulphochlorinated paraffin</td>
<td>3.9</td>
<td>5,000</td>
<td>12,700</td>
<td>4,858</td>
<td>0.36</td>
</tr>
<tr>
<td>9 Synthetic oils</td>
<td>3.7</td>
<td>2,900</td>
<td>12,900</td>
<td>5,418</td>
<td>0.42</td>
</tr>
<tr>
<td>10 Fatliquoring polymer</td>
<td>3.8</td>
<td>2,800</td>
<td>15,100</td>
<td>2,567</td>
<td>0.17</td>
</tr>
<tr>
<td><strong>Average reference values</strong></td>
<td>3.8</td>
<td>2,750</td>
<td>15,360</td>
<td>6,089.6</td>
<td>0.39</td>
</tr>
</tbody>
</table>

As to residual bath characterisation, it was noted that the polluting load of all baths was quite similar, in such a way that none of the assessed families of products stood out for a lower environmental impact.

All the technical issues related to Action 2 are analyzed and defined in detail in the Annex of Deliverables as Action 1-2: Deliverable D5 “Study on fatliquoring agents environmental impact”. As scheduled, this action has been completed by 100%.

5.1.3 Action 3 Natural products demonstration and evaluation

**Activity 3.1: Lab-scale screening of molecules or molecule alternative to chloroparaffins or chlorosulphonated paraffins**

This action started on March 2012 and it was completed in March 2013 by Serichim.

As reported in Action 1, CPs and SCPs are members of a wide population of products, characterized by structural and physical properties. In order to demonstrate that they can be substituted, it was necessary to verify that it is possible to cover similar ranges of the relevant characteristics starting by renewable raw materials. As significant properties the following
ones were identified: (i) total chlorine content, (ii) active chlorine content, (iii) viscosity as a function of temperature, (iv) density as a function of literature.

A wide number of small scale samples of chloroparaffins and of chlorinated fatty acid methyl esters were prepared and characterised for the selected properties. A mathematical model was developed, able to predict physical properties as a function of carbon chain length, both for paraffins (reference materials) and esters (new replacing materials). It was assessed that it is possible to cover the same ranges of properties (for details see Annex of Deliverables).

As it was said before, possible substitutes for chlorosulphonated paraffins were identified, and have to be prepared in order to complete this Action.

In this action the plan is to synthesized and evaluated four esterified vegetable fatty acid derivatives as substitute of chlorinated paraffins and solfochlorinated paraffin:
- Methyl stearate (chlorinated and solfochlorinated, CMS and SCMS, respectively)
- Methy Esters of palm oil acids (Palmkernel oil) (chlorinated and solfochlorinated, CI-FAME and SCI-FAME)

We actually prepared and tested also other products (fatty acid mixture and fatty acids methyl esters) in addition to the planned ones with the aim of collecting more information on their interaction with protein substrate and get further insight their mechanism of interaction with leather proteins. CMS was produced with 4 different Cl percentages in order to evidence the role of chloride content. Esterified vegetable fatty acid derivatives were synthesized and evaluated to the kilo-lab scale as substitutes for chloroparaffins.

Selection criteria were based on the carbon chain lenght C14 – C17 and introducing the same chlorine and sulphur content as in benchmark products Chloparin 44F and Chloparten Z. The selected products under investigation were:

- CHLORINATED METHYL STEARATE (Lot: 120712 Amount: 2,00 kg- July 2012) 34,4% Chlorine, corresponding an approximate average number of 3 Cl/molecule (CMS34).
- CHLORINATED METHYL STEARATE (Lot.: 120710D Amount: 0,20 kg-July 2012) 37.9/ Chlorine, corresponding an approximate average number of 3.2 Cl/molecule (CMS38).
- CHLORINATED METHYL STEARATE (Lot.: 120710B Amount: 0,20 kg- July 2012) 21.3% Chlorine, corresponding an approximate average number of 1.8 Cl/molecule (CMS21).
- CHLORINATED METHYL STEARATE (Amount: 0,20 kg- September 2012) 44% Chlorine (CMS44).
- METHYL STEARATE SULFO CHLORINATED (Lot.: 120925 Amount: 1,5 kg- September 2012), corresponding an approximate average number of 1.8 Cl/molecule (SCMS), with sulfur content comparable with Cloparten Z10S.
- CHLORINATED PALMKERNEL OIL FAME (Lot 130116, 47,5 % m/m Chlorine content).
- SULFO CHLORINATED PALMKERNEL OIL FAME (Lot 130404, 38,0 % m/m Chlorine content 8,6% m/m sulfur content)
- SULFO CHLORINATED PALMKERNEL OIL FAME (Lot 130118, 24.1 % m/m Chlorine content 8,6% m/m sulfur content-1,5 Kg)

Investigation on natural products substitutes of chloroparaffins: chlorinated methyl stearate (CMS), CI-FAME, FAME, CI-FA, Chlorinated Palmkernel Oil FAME.

Chlorinated methyl stearate (CMS) is the clorurated species of methyl stearate (CH₃-(CH₂)₁₆-COO-CH₃). These compounds have been tested with different percentage of chlorine functionalities and analyses by FTIR in order to study if a specific Cl concentration gives an optimal interaction with the substrate. This action has been developed from month 3 to month 15 of the project development.
FTIR spectra show a correlation between Cl content determined by the method of analysis ASTM E 256-88 and the decrease of the band assigned to CH stretching vibrations as well as to the increase of the bands assigned to C-Cl stretching (see Annex of Deliverables). Wet GSA and CL (100 g powder + 500 uL water) were treated with CMS21, CMS34 and CMS38 and CMS44 (dissolved in methanol, 50 mg/mL) with has been started. CMS samples were dissolved in methanol (50 mg/mL) (procedure A). Another procedure was agreed with COLORTTEX to simulate the actual leather treatment. One g of GSA or CL was treated with 1 g of CP30 or CP44 (for comparison) or CMSs or Cl-FAME or FAME or Cl-FA or chlorinated or not-chlorinated Palmkernel Oil FAME. The mixture was stirred for 10 min at 30°C or 60°C, rinsed (3-4 times) in hexane to remove the excess of fatting agent and dried in air before analysis (procedure B). The protocols of analysis are reported in the Annex of Deliverables.

The results obtained on CMS-treated CL and gelatins are summarized below.

CMSs interact with CL, GSA and GSB and this interaction is more effective in CMS at higher Cl content (CMS38 and CMS 44). As observed for CPs, FTIR did not show any band suggestive of newly formed covalent bond. Therefore, this interaction can be classified as not covalent ad due to electrostatic interactions (ionic bonds between Asp- and Lys+ and hydrogen bonds), hydrophobic interactions and Van der Waals forces.

Following the B procedure, the results agreed with data obtained in A procedure. It is interesting to observe that also chlorinated FAME and not chlorinated FAME, chlorinated Palmkernel Oil FAME and not chlorinated Palmkernel Oil FAME interact with gelatin, demonstrating the possibility of using not chlorinated natural compounds.

The results obtained helped us to elucidate the chemical mechanism of interaction of chlorinated compounds with leather proteins. Chlorinated compounds have indeed only one functional group (Cl) that give us all the information on this kind of substitution products. The comparison of these results with those obtained with chlorosulfinated products gave information to study specifically the interaction mechanism of SO2Cl group with leather proteins.

Investigation on natural products substitutes of solfochloroparaffins: solfochlorinated methyl stearate (SCMS), solfochlorinated Palmkernel Oil FAME.

The study of the interaction of the natural products developed by SERICHIM for the substitution of solfochloroparaffins was also completed. 1.5 g of GSA or CL were treated with 5.4 mL of NaHCO3 saturated solution stirring for 10 min at 30°C or 60°C. Then, 0 (blank), 300 (20% w/w of protein) or 900 mg (70% w/w of protein) of SCP (as comparison) or SCMS or solfochlorinated Palmkernel Oil FAME were added and the mixture incubated at 30 or 60°C for 30 min. Thirty degrees is the temperature typically used during tanning process; 60°C was investigated to explore different operating conditions. After this 300 or 900 mg PEG 200 (polyethyleneglycol) were added in order to remove the excess SCP, stirring for 10 min. The modified gelatin or CL was rinsed with MilliQ water and centrifuged (3000 g for 10 min) until the solution reached a neutral pH. The samples were dried in air before the analysis. For collagen the same procedure was scaled up (because of the high cost of pure collagen) using 36 mg of pure collagen in each experiment and only the treatment with 70% SCP was performed.

As described in detail in the Annex of Deliverables, all the solfochlorinated natural products strongly interact with GSA, collagen and CL. FTIR spectra showed new absorption suggestive of the formation of sulfonamide bonds.

The application trials performed by COLORTTEX (described in the following Action 4) suggest a quite good performance of the new developed chemicals compared with the standard ones. These results indicate that the assumptions described in the planned project are correct and the project can run as indicated in the future steps.
All the technical issues related to Action 3 are analyzed and defined in detail in the Action 3 Deliverables (D1 and D2 “Natural Products”). As scheduled, this action has been completed by 100%.

5.1.4 Action 4 Environmental demonstration of natural products at laboratory level.

This action started in July and it was completed in March 2013. COLORETEX and SERICHIM produced standard samples, taking chlorine and chlorosulfonated paraffins as a reference, analyzing and assessing the performances of reference samples. In particular during this action phase SERICHIM focused his activity in the production of Palm Kernel Oil based substitutes of chlorinated and sulphochlorinated paraffins at kg lab-scale. COLORETEX produced leathers from bovine and ovicaprine raw hides tanned with standard chrome tanning and fatliquored with a specific formulate containing a defined amount of the natural product CMS38 compared with CP44. The treatment was performed to produce soft nappa and nubuk articles. CMS38 was selected to develop the application test because its physical properties were similar to CP44. Figures 4A and B shows the pictures of samples of chrome tanned leather treated by COLORETEX with CP44 (left) and CMS38 (right) fatliquoring formulation.

![Figure 4](image1.png)

**Figure 4.** Samples of chrome tanned leather treated by COLORETEX with CP44 (left) and CMS38 (right) fatliquoring formulation.

No remarkable differences were observed in FTIR spectra. However, some different physical properties (see below) were revealed. This confirms that theoretical assumptions made in the project planning were correct. The articles obtained were quite similar. The differences observed among CMS38- and CP44-treated samples are the following:
- CMS38-treated samples were lightly hard, with an oily touch (not so silky), more shining, and they present a better “writing effect” (on nubuk articles), with very good buffing properties.

To better understand the effect of the new naturals products on leather, COLORETEX performed also different trials on chrome tanned leather (Figure 5A) and vegetable tanned leather (Figure 5B) using CP44 and CMS38 as finishing chemical. In this process the product is applied on leather by using roller coating machine. Due to this application most of the chemicals were localized only on the leather surface.
The differences observed on these samples were analogous to those reported above. However, several features were more evident. On vegetable tanned leather we can observe a reduced “waxy” effect of CMS38. This effect can be explained on the basis of FTIR results (see Annex of Deliverables) that showed that an highest chlorine content improves the interaction with the protein matrix. Thus, a reduced Cl percentage in CMS38 compared with CP44 may increase the penetration of this chemical through the section of treated leather, which is responsible for the reduced “oily” surface.

From this experience developed in Action 3 and 4 we understood that Cl content is fundamental for the chemical performance of the product and that the right comparative chemical of CP44 will be a CMS derivate containing 44 w/w% Cl substitution. However, the physical characteristics of this chemical will be different from CP44.

From these results emerge that structural chemical characteristic more than physical properties are important to obtain similar application results. Good results were also obtained on leather samples using SCMS (Figure 6). However the best results were obtained using Cl-Palmkernel oil (as substitute of CPs) and SC-l-Palmkernel oil FAME (as substitute of SCP).

For the quality characteristics of the products, these two compounds were definitely selected for the future semi-industrial and pre-industrial actions.
Once these products were selected by COLORTEX and SERICHIM, and after the characterisation of the 10 reference fatliquoring product families, the same laboratory tests were conducted in INESCOP on the natural-origin products developed in the project (Figure 7).

![Image](image_url)

**Figure 7.** Laboratory tests on the natural-origin products at INESCOP facilities

The results obtained in these tests were compared with the reference values so as to be able to assess the improvement of the environmental impact of the products developed, always maintaining the quality of leather.

Concerning the appearance of the leather samples obtained, in all cases the assessed fatliquoring products conferred adequate softness, fullness and flexibility on the leather. Some differences in shade were observed, which were not considered significant.

Table 4 shows the results obtained in the tests using the natural fatliquoring products selected as optimum for the fatliquoring stage (laboratory scale test with bovine leather):

<table>
<thead>
<tr>
<th>Reference</th>
<th>pH</th>
<th>Conductivity (µS/cm)</th>
<th>COD (mg O₂/l)</th>
<th>BOD₅ (mg O₂/l)</th>
<th>Biodegradability (BOD₅ / COD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-10 Fatliquoring product families’ average</td>
<td>3.8</td>
<td>2,750</td>
<td>15,360</td>
<td>6,290</td>
<td>0.41</td>
</tr>
<tr>
<td>CP (44 % Cl)</td>
<td>3.3</td>
<td>6,500</td>
<td>12,600</td>
<td>5,540</td>
<td>0.44</td>
</tr>
<tr>
<td>Chlorinated paraffin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CI-FAME (48.6 % Cl)</td>
<td>3.2</td>
<td>5,100</td>
<td>12,800</td>
<td>7,170</td>
<td>0.56</td>
</tr>
<tr>
<td>Chlorinated vegetable fatty acid methyl ester</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCP (44 % Cl)</td>
<td>2.4</td>
<td>12,100</td>
<td>10,300</td>
<td>4,225</td>
<td>0.41</td>
</tr>
<tr>
<td>Chlorinated paraffin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCI-FAME (38 % Cl- 8.6 % S)</td>
<td>2.4</td>
<td>10,200</td>
<td>5,440</td>
<td>2,990</td>
<td>0.55</td>
</tr>
<tr>
<td>Sulpho-chlorinated vegetable fatty acid methyl ester</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results obtained show that the biodegradability of the FAME fatliquoring bath samples (based of fatty acid methyl esters) improves by 34 - 36% with respect to the average value of the assessed fatliquoring products (1-10 product families).

Furthermore, the leather samples obtained during the tests on a laboratory scale were subjected to different quality control processes according to international standards (EN-ISO) to test their suitability to be used in the manufacture of footwear components. Table 5 shows the results of the physical characterisation of the bovine hides.
Table 5. Physical characterisation of bovine leather (laboratory scale tests)

<table>
<thead>
<tr>
<th>Reference</th>
<th>Tear strength (N)</th>
<th>Tensile strength (N/mm²)</th>
<th>Elongation at break (%)</th>
<th>Matter soluble in Cl₂CH₂ (% m.s.)</th>
<th>Chromium(VI) (mg/kg) (*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-10 Average</td>
<td>156</td>
<td>17</td>
<td>72</td>
<td>4.4</td>
<td>14.3</td>
</tr>
<tr>
<td>CP</td>
<td>85</td>
<td>10.7</td>
<td>49.3</td>
<td>8.6</td>
<td>2.6</td>
</tr>
<tr>
<td>Cl-FAME</td>
<td>119</td>
<td>20.3</td>
<td>66.0</td>
<td>7.7</td>
<td>2</td>
</tr>
<tr>
<td>SCP</td>
<td>331</td>
<td>25.4</td>
<td>85.3</td>
<td>10.1</td>
<td>2.3</td>
</tr>
<tr>
<td>SCI-FAME</td>
<td>214</td>
<td>21.4</td>
<td>78.9</td>
<td>10.1</td>
<td>1.8</td>
</tr>
<tr>
<td>Recommended values</td>
<td>&gt;150</td>
<td>&gt;15</td>
<td>&gt;40</td>
<td>&gt;3</td>
<td>&gt; 3</td>
</tr>
</tbody>
</table>

(*) After ageing

The determination of the physical parameters of leather demonstrated that the recommended values for the manufacture of footwear were fulfilled.

All the technical issues related to Action 4 are analyzed and defined in detail in the Annex of Deliverables as Action 4: Deliverables D1 and D2 “Environmental demonstration of natural products at laboratory level”. As scheduled, this action has been completed by 100%.

5.1.5 Action 5 Fatting at a semi-industrial level by using natural products.

This action started in July 2012 and it was completed on 30 June 2013.

Different types of raw hides (from bovine, sheep and goat) were selected by COLORTEX and INESCOP and we started the tanning process to stabilize leather proteins and provide a good leather’s storage.

SERICHIM studied the scale up of the pilot production of Cl-Palmkernel oil, as substitute of CPs, and SCI-Palmkernel oil, as substitute of SCP. For the pre-industrial step SERICHIM produced several samples, the last of which, in amount of 2 kg of products, were enough for the preliminary experiments in COLORTEX and INESCOP.

In order to rely on an effective apparatus to provide – at “few kilograms scale “ – chlorinated and sulphochlorinated samples, a specific equipment for carrying out chlorination reactions was studied, assembled and operated.

Figure 8 shows the pilot plant located in SERICHIM laboratories used for the pre-industrial production. This will be scaled up and used also for the industrial-scale production.

![Figure 8](image-url)
SERICHIM activity was therefore constantly devoted to the production of kg samples that was targeted – on the basis of the indications coming from downstream project partners - as the most promising both in terms of industrial effectiveness and reproducibility and also in terms of “environmental friendship“.

More precisely, on the basis of the results obtained from previous actions 2 and 3 and following discussion with project partners, mainly COLORTEX and ICCOMCNR it was established:

1) the Palmkernel Oil as the most suitable natural origin substrate to be chlorinated and sulphochlorinated as alternative to currently used chlorination and sulpho-chlorination of n-paraffins. A commercially available product PALM KERNEL OIL was used being his composition the following as far as the distribution of alkyl chain lengths was concerned:

<table>
<thead>
<tr>
<th>Component</th>
<th>Weight % m/m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capric acid (C_{10}) Methyl ester</td>
<td>0 - 3,0</td>
</tr>
<tr>
<td>Lauric acid (C_{12}) Methyl ester</td>
<td>54,0 - 59,0</td>
</tr>
<tr>
<td>Myristic acid (C_{14}) Methyl ester</td>
<td>17,0 - 21,0</td>
</tr>
<tr>
<td>Palmitic acid (C_{16}) Methyl ester</td>
<td>8,0 - 11,0</td>
</tr>
<tr>
<td>Oleic acid (C_{18}) Methyl ester</td>
<td>9,0 - 17,0</td>
</tr>
</tbody>
</table>

2) to increase chlorine content in the sulpho-chlorinated product compared to previous Palm kernel Oil based samples – as per above mentioned Lot 130116 and Lot 130118 supplied to COLORTEX and ICCCOMCNR

The following samples were prepared and supplied to COLORTEX and to INESCOP

<table>
<thead>
<tr>
<th>Lot no:</th>
<th>Quantity (kg)</th>
<th>Sent to</th>
<th>Density at 25 °C (g/L)</th>
<th>Viscosity at 25 °C (cSt)</th>
<th>Viscosity at 40 °C (cSt)</th>
<th>Chlorine content (%m/m)</th>
<th>Test report</th>
</tr>
</thead>
<tbody>
<tr>
<td>130116</td>
<td>2,0</td>
<td>COLORTEX</td>
<td>1287</td>
<td>1849</td>
<td>355</td>
<td>47,5</td>
<td>2013/002</td>
</tr>
<tr>
<td>130422</td>
<td>2,7</td>
<td>INESCOP</td>
<td>1319</td>
<td>3316</td>
<td>684</td>
<td>48,6</td>
<td>2013/012</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lot no:</th>
<th>Quantity (kg)</th>
<th>Sent to</th>
<th>Density at 25 °C (g/L)</th>
<th>Chlorine content (%m/m)</th>
<th>Sulfur content (%m/m)</th>
<th>Test report</th>
</tr>
</thead>
<tbody>
<tr>
<td>130118</td>
<td>2,2</td>
<td>COLORTEX</td>
<td>1161</td>
<td>24,1</td>
<td>8,2</td>
<td>2013/003</td>
</tr>
<tr>
<td>130404</td>
<td>1,0</td>
<td>COLORTEX</td>
<td>1317</td>
<td>38,0</td>
<td>8,6</td>
<td>2013/007</td>
</tr>
<tr>
<td>130520</td>
<td>1,8</td>
<td>INESCOP</td>
<td>1317</td>
<td>38,0</td>
<td>8,6</td>
<td>2013/007</td>
</tr>
</tbody>
</table>

Simultaneously COLORTEX ran preliminary tests on selected leather samples were performed by using the selected natural products (Cl-Palmkernel oil, as substitute of CPs, and SCI-Palmkernel oil, as substitute of SCP), optimizing a protocol (formulations) for the hide treatment.

After completing the laboratory-scale tests using the products that had been selected by COLORTEX and SERICHIM, the same semi-industrial scale tests were conducted in
INESCOP on the natural-origin products developed in the project. As in Action 4, the results obtained in these tests were compared with the reference values so as to be able to assess the improvement of the environmental impact of the products developed, always maintaining the quality of leather.

Concerning the appearance of the leather samples obtained, in all cases the assessed fatliquoring products conferred adequate softness, fullness and flexibility on the leather. Some differences in shade were observed, which were not considered significant.

Table 6 shows the results obtained so far in the tests using the natural fatliquoring products selected as optimum for the fatliquoring stage (semi-industrial scale test with bovine leather):

![Table 6](image)

The tests completed so far show that the biodegradability of the FAME fatliquoring bath samples (based of fatty acid methyl esters) improves by 27-34% with respect to the average value of the assessed fatliquoring products (1-10 product families).

Furthermore, the leather samples obtained during the tests on a semi-industrial scale were subjected to different quality control processes according to international standards (EN-ISO) to test their suitability to be used in the manufacture of footwear components (Figure 9).

Table 7 shows the results of the physical characterisation of the bovine hides.

![Table 7](image)

The determination of these physical parameters on leather demonstrated that the recommended values for the manufacture of footwear were fulfilled.
In parallel with these trials, the determination of the volatile matters present in the leathers fatliquored with the ECOFATTING products has been carried out on a semi-industrial scale. Thus, we can assess the feasibility of using these products in the fatliquoring of leather for car upholstery by means of the test called "fogging test". Table 8 shows the results obtained in the leathers produced in semi-industrial scale tests:

**Table 8. Fogging test results on bovine fatliquoring leather (semi-industrial scale tests)**

<table>
<thead>
<tr>
<th>Reference</th>
<th>Condensed volatile compounds (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorinated paraffin (44 % Cl)</td>
<td>33,5</td>
</tr>
<tr>
<td>Chlorinated vegetable fatty acid methyl ester (48.6 % Cl)</td>
<td>19,2</td>
</tr>
<tr>
<td>Sulpho-chlorinated paraffin (44 % Cl)</td>
<td>95,7</td>
</tr>
<tr>
<td>Sulpho-chlorinated vegetable fatty acid methyl ester (38 % Cl- 8.6 % S)</td>
<td>24,1</td>
</tr>
<tr>
<td><strong>Recommended values</strong></td>
<td><strong>&lt; 5</strong></td>
</tr>
</tbody>
</table>

The results show that all products have fogging test values much higher than those recommended by the automobile manufacturers.

Moreover, comparing between synthetic and natural products with the same treatment, there was a reduction 43% in the fogging test on chlorinated products (CI-FAME respect to CPs) and by 75% on sulpho-chlorinated products (SCI-FAME respect to SCPs), which is a significant improvement of natural products compared to synthetic ones.

Also, biodegradability test on leathers fatliquored with the ECOFATTING products has been carried out. Through these tests, according to the fatliquoring product employed, we can estimate the degree of biodegradability of leathers, which allows us to compare between the different products regarding their waste environmental impact.

In the test carried out, comparing between synthetic and natural products with the same treatment, there was an increase by 36% in the biodegradability on chlorinated products (CI-FAME respect to CPs) and by 20% on sulpho-chlorinated products (SCI-FAME respect to SCPs), which is a significant improvement of natural products compared to synthetic ones (Figure 10).
These results show a significant improvement in the biodegradation of waste coming from leather fatliquored with products from natural origin and support the use of these products as an alternative to syntetic fatliquorings in the leather tanning process, since the waste generated are biodegradable and therefore more easily to be treated.

Environmental validation was performed by INESCOP and ENEA. This action has been fundamental to adjust and control the fatting process at a pre-industrial level. All the technical issues related to Action 5 are analyzed and defined in detail in the Annex of Deliverables as Action 5: Deliverables D1 and D2 “Environmental demonstration of natural products at semi-industrial level”. As scheduled, this action has been completed by 100%.

5.1.6 Action 6. Environmental demonstration of natural products fatting at a pre-industrial level.

This action started in October 2012 and it was completed in September 2013. In order to achieve the target of environmental demonstration at pre-industrial level, availability of selected Palmkernel Oil based chlorinated and sulpho-chlorinated products have to be granted to project partners at “ten kilograms” level by SERICHIM. A new pilot plant was built by Serichim, with a photochemical reactor of 5 L volume (instead of the previous of 2 L, Figure 11)
Figure 11. 5 L reactor for semi-industrial production located in SERICHIM laboratories used for the production of natural products.

The following samples were prepared and supplied to COLORTEX and to INESCOP:

<table>
<thead>
<tr>
<th>Lot no:</th>
<th>Quantity (kg)</th>
<th>Sent to</th>
<th>Density at 25 °C (g/L)</th>
<th>Viscosity at 25 °C (cSt)</th>
<th>Viscosity at 40 °C (cSt)</th>
<th>Chlorine content (%m/m)</th>
<th>Test report</th>
</tr>
</thead>
<tbody>
<tr>
<td>130520</td>
<td>7,2</td>
<td>COLORTEX</td>
<td>1306</td>
<td>2914</td>
<td>548</td>
<td>48,2</td>
<td>2013/017</td>
</tr>
<tr>
<td>130529</td>
<td>7,7</td>
<td>INESCOP</td>
<td>1302</td>
<td>2869</td>
<td>546</td>
<td>48,1</td>
<td>2013/018</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lot no:</th>
<th>Quantity (kg)</th>
<th>Sent to</th>
<th>Density at 25 °C (g/L)</th>
<th>Chlorine content (%m/m)</th>
<th>Sulfur content (%m/m)</th>
<th>Test report</th>
</tr>
</thead>
<tbody>
<tr>
<td>130604</td>
<td>7,6</td>
<td>COLORTEX</td>
<td>1334</td>
<td>39,0</td>
<td>8,6</td>
<td>2013/020</td>
</tr>
<tr>
<td>130611</td>
<td>7,5</td>
<td>INESCOP</td>
<td>1334</td>
<td>39,2</td>
<td>8,0</td>
<td>2013/021</td>
</tr>
</tbody>
</table>

This scale of production would be very time consuming and too “operational intensive“, if approached with the existing apparatus. For this reason SERICHIM proceeded to the set up a semi-industrial apparatus able to carry out chlorination and sulpho-chlorination reactions of organic substrates based on the original know how of SERICHIM on “CONTINUOUS FLOW TECHNOLOGY”. This technology has many advantages very important in case of a future industrial production:

- High volume production with a small equipment compared to the traditional batch photochlorination reactors
- Increase of safety in the production process due to lower hold up involved
- Constant quality
- Low operational cost and fixed investment required
At the same time COLORTEX has already bought raw hides for this action. All hides were pre-tanned making them ready for the process of fatting with natural products (wet blue for Cl-Palmkernel oil FAME and pickled for SCI-Palmkernel oil FAME). The industrial production of leathers tanned with the natural products will start in the Italian and Spanish tanneries as 100 Kg of natural products (Cl-Palmkernel oil FAME as substitute of CPS and SCI-Palmkernel oil FAME as substitute of SCP) will be ready (see Action 5: between May 31st and June 15th 2013).

ICCOMCNR and ENEA set up chemical-physical tests (FTIR spectroscopy, termogravimetric analysis, TGA, scanning electron microscopy, SEM) to assess the quality of leather samples produced with the new method. These tests have been set up using leather samples prepared in Actions 4 and 5.

After the laboratory scale and pre-industrial scale tests with the products selected by COLORTEX and SERICHIM, the pre-industrial scale tests were conducted in a Spanish tannery named VERDE VELENO, S.L. located in Bétera (Valencia), by using the natural-origin products developed in the project. The results obtained in these tests were compared with the reference values so as to be able to assess the improvement of the environmental impact of the products developed, always maintaining the quality of leather (Figure 12).

Concerning the appearance of the leather samples obtained, in all cases the assessed fatliquoring products conferred adequate softness, fullness and flexibility on the leather.

Table 9 shows the results obtained in the pre-industrial scale tests with bovine leather, using the natural fatliquoring products selected as optimum for the fatliquoring stage.

<table>
<thead>
<tr>
<th>Reference</th>
<th>pH</th>
<th>Conductivity (µs/cm)</th>
<th>COD (mg O₂/l)</th>
<th>BOD₅ (mg O₂/l)</th>
<th>Biodegradability (BOD₅/COD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-10 Fatliquoring product families' average</td>
<td>3.6</td>
<td>1,982</td>
<td>11,500</td>
<td>2,844</td>
<td>0.27</td>
</tr>
<tr>
<td>Cl-FAME</td>
<td>3.7</td>
<td>3,640</td>
<td>10,300</td>
<td>4,110</td>
<td>0.40</td>
</tr>
<tr>
<td>Chlorinated vegetable fatty acid methyl ester (48.6 % Cl)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCI-FAME</td>
<td>3.7</td>
<td>4,830</td>
<td>7,900</td>
<td>2,980</td>
<td>0.38</td>
</tr>
<tr>
<td>Sulpho-chlorinated vegetable fatty acid methyl ester (38 % Cl- 8.6 % S)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The tests carried out show that the biodegradability of the Cl- and SCI-FAME fatliquoring bath samples (based of fatty acid methyl esters) improves by 41 – 48% with respect to the average value of the assessed fatliquoring products (1-10 product families).

Figure 12. Fatliquoring test on a pre-industrial scale at VERDE VELENO facilities
Regarding to the quality of the obtained leathers, the determinations of physical and chemical parameters in accordance with standard test have shown to be compliant with the limits required for footwear manufacture and the determination of these physical parameters of leather demonstrated that the recommended values for the manufacture of footwear were fulfilled.

Environmental validation was performed by INESCOP and ENEA. This action has been fundamental to adjust and control the fattering process at a pre-industrial level. All the technical issues related to Action 6 are analyzed and defined in detail in the Annex of Deliverables as Action 6: Deliverables D1 and D2 “Environmental demonstration of natural products at pre-industrial level”. As scheduled, this action has been completed by 100%.

5.1.7 Action 7 Environmental demonstration of hides fatted with natural products

The quality assessment of the production of footwear with hides fatted with natural products carried out by INESCOP through chemical validations in accordance with accepted standards (EN, ISO, etc.), proved that ECOFATTING leathers were compliant with the criteria of the European Eco-label for footwear (Decision 2009/563/EC).

Table 10. Chemical validations on ECOFATTING leathers

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>Limits established by the European Eco-label for footwear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromium (VI)</td>
<td>&lt; 3 ppm</td>
</tr>
<tr>
<td>Arsenic (As)</td>
<td>&lt; 65 ppm</td>
</tr>
<tr>
<td>Cadmium (Cd)</td>
<td>&lt; 3 ppm</td>
</tr>
<tr>
<td>Lead (Pb)</td>
<td>&lt; 8 ppm</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>&lt; 150 ppm</td>
</tr>
<tr>
<td>Pentachlorophenol</td>
<td>&lt; 0.1 ppm</td>
</tr>
<tr>
<td>Aromatic amines (derived from azo colorants)</td>
<td>&lt; 30 ppm</td>
</tr>
</tbody>
</table>

Then, the suitability of these leathers was proven by manufacturing different footwear styles at INESCOP (Figure 13) and leather-goods and leather garments at COLOTEX (Figure 14).
5.1.8 Action 8 Study of the demonstration about the environmental benefits from the natural products fatting process

In this stage has been collected the results of the environmental demonstration of the hides fatted with ECOFATTING natural products through the collection of feedback information of the production of footwear and leather articles. To achieve this, several meetings were held with footwear and leather-goods companies in order to collect information about the performance of these leathers in the production of footwear and other leather articles.

With regard to footwear production, the main problems that may be caused by the use of this type of fatliquoring products could lead to wrong joining of the leather upper to the sole. The joining operation can be carried out by injection, vulcanisation, cementing or sewing, the latter being the least risky one. In this context, four different footwear types were produced: footwear with outer soles injected, footwear with vulcanized sole, footwear with outer soles glued and footwear with outer soles stitched.

Figures 15-18 show a selection of the footwear styles manufactured, in which a good performance of hides fatted with products of natural origin was observed throughout the various process stages (cutting, closing, setting, and finishing).
INESCOP has been in continual contact with the footwear company in order to collect feedback information and identify strong/weak points in the production of shoes when using hides fatted with products of natural origin and to analyse different issues such as possible problems, benefits, etc.

This was aimed to collect information about the use of hides fatted with products of natural origin in the different stages of the footwear manufacturing process. More specifically, this was aimed to identify possible differences between the use of these fatliquoring product and other commercial products of synthetic origin, along with any subsequent modifications in the production process.

The results of these tests and the appearance of the footwear manufactured proved the satisfaction of the footwear company in producing articles using hides fatted with products of natural origin.

With regard to leather-goods and garment production, since the physical properties of leathers are similar, breaking, sewing and slip operations have been made as usual and no problems have been observed. Furthermore, we have not observed corrosion problems in metal parts (studs, fastenings and zippers) in contact with hides fatted with products of natural origin.

Figures 19 to 21 show a selection of leather-goods and garment articles manufactured, in which a good performance of the ECOFATTING leathers was observed throughout the various process stages.

**Figures 19-21.** Leather-goods and garment articles

Likewise, the manufacturing process (Figure 22) was carried out as usual and no differences were observed in the processes or in the final appearance of the models produced.

**Figure 22.** Vulcanised footwear manufacture process and sewing of leather-goods with ECOFATTING leathers
All the technical issues related to Action 8 are analyzed and defined in detail in the Annex of Deliverables as Action 7&8: Deliverable “Environmental demonstration of hides fatted with natural products”. As scheduled, this action has been completed by 100%.

5.1.9 Action 9. Quality assessment of leather products production

The leather samples obtained during the tests on a laboratory, semi-industrial and pre-industrial scale were subjected to different quality control processes according to international standards (EN-ISO) to test their suitability to be used in the manufacture of footwear components. The table below shows the selected control parameters and the testing standards used:

**Table 11.** Standards used in the physical validations of fatliquored hides.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>STANDARD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength (N/mm²)</td>
<td>ISO 3376:2002 (IULTCS/IUP 6) Determination of tensile strength and percentage extension</td>
</tr>
<tr>
<td>Elongation at break (%)</td>
<td>ISO 3376:2002 (IULTCS/IUP 6) Determination of tensile strength and percentage extension</td>
</tr>
<tr>
<td>Grain burst (mm)</td>
<td>ISO 3379:1976 (IULTCS/IUP 9) Determination of distension and strength of grain -- Ball burst test</td>
</tr>
</tbody>
</table>

Tables 12 shows the results of the physical characterisation of ECOFATTING leather at pre-industrial scale comparing with the fatliquoring product families’ average and the recommended values for footwear manufacture.

**Table 12.** Physical characterisation on sheepskins (pre-industrial scale tests)

<table>
<thead>
<tr>
<th>Reference</th>
<th>Tear strength (N)</th>
<th>Tensile strength (N/mm²)</th>
<th>Elongation at break (%)</th>
<th>Grain burst (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-10 Fatliquoring product families’ average</td>
<td>230</td>
<td>18.1</td>
<td>82.5</td>
<td>&gt;8</td>
</tr>
<tr>
<td>CI-FAME Chlorinated vegetable fatty acid methyl ester (48.6 % Cl)</td>
<td>96</td>
<td>16.2</td>
<td>60.2</td>
<td>&gt;10</td>
</tr>
<tr>
<td>SCI-FAME Sulpho-chlorinated vegetable fatty acid methyl ester (38 % Cl- 8.6 % S)</td>
<td>115</td>
<td>18.4</td>
<td>65.3</td>
<td>&gt;10</td>
</tr>
<tr>
<td>Recommended values</td>
<td>&gt;50</td>
<td>&gt;15</td>
<td>&gt;40</td>
<td>&gt;8</td>
</tr>
</tbody>
</table>
The determination of the physical parameters on ECOFATTING leather samples (Figure 23) demonstrated that the recommended values for the manufacture of footwear were fulfilled.

All the technical issues related to Action 9 are included in detail in the Annex of Deliverables as Action 4 Deliverables about “Environmental demonstration of natural products at laboratory level”, Action 5 Deliverables about “Environmental demonstration of natural products at semi-industrial level” and Action 6 Deliverables about “Environmental demonstration of natural products at pre-industrial level” As scheduled, this action has been completed by 100%.

5.1.10 Action 10. Demonstration of technical economic viability

Leather production is an important European sector, with 25% of world trade and in evolution. In the perspective of global market, exports become more important (i.e. towards China) and the use of renewable sources for input materials/compounds becomes fundamental. Substitution of CPs products will be appreciated in particular by Chinese market, which looks both at price and to innovation and ecofriendly products.

The reduction of environmental impact was demonstrated. The evaluation of the impact of the natural fatliquoring on wastewater was achieved by the characterization of the fatliquoring waste-baths obtained. The tests show that the biodegradability of the Cl- and SCI-FAME fatliquoring bath samples (based on fatty acid methyl esters) improves by 22 - 68% with respect to the average value of the assessed fatliquoring products (1-10 product families).

Moreover, when comparing between synthetic and natural products with the same treatment, there was an improvement between 9 - 30% in the biodegradability on chlorinated products (Cl-FAME with respect to CPs) and between 25 - 42% on sulpho-chlorinated products (SCI-FAME with respect to SCPs).

Finally, the biodegradability tests on fatliquored leathers showed a significant improvement by natural products compared to synthetic ones, which implies a lower impact of the waste generated in the tanning process.

Furthermore, the economic viability resulted for:
- use of Sulpho Chlorinated Palmkernel FAME (instead of CLOPARTEN Z),
- use of Chlorinated Palmkernel FAME (instead of CLOPARIN 44F).
Economic benefits could become more important with a scale change in chlorination and sulpho-chlorination plants, which could affords lower production prices.

Recent discussions on the reduced availability and pricing of some foods crops on the global market started a thought debate about the preference of crops for food use in front of those dedicated to the industrial production of chemicals or energy (biomass, ethanol, biodiesel and so on). Although it is widely believed that energy crops can be, eventually, only one of the reasons of the supposed reduction in the production of foodstuffs, there is no doubt that the discussion raised an adverse mood against the use of food crops for not food industrial applications.

With the aim to overcome this difficulty, SERICHIM successfully explored an alternative raw material to palm kernel oil using, as feedstock, crude acid animal fats, deriving from the fleshing step in tannery industry.

Fleshing is a typical by-product from tannery process and it is treated as a waste (tanneries pay for disposal). This feedstock contains 10-15 % of fat as triglycerides. Industrial processes already use fleshing for protein hydrolizate recovering, obtaining as by-product a sterile fat, that, due to the high free fatty acid content (up 10-20%), has poor commercial value (ca. 0,15-0,25 €/kg).

SERICHIM is owner of DeACIDO technology, a process developed in 2008 for using high acidity animal fats and vegetable oils as raw materials for biodiesel, making those materials an ethical alternative to food sources for this production.

The DeACIDO technology applies to the esterification of free fatty acids (FFA) present in fats and oils: it represents a first section of the triglycerides transesterification process with methanol to produce Fatty Acid Methyl Esters (FAME) and glycerol (Figure 24).

![Figure 24. Scheme of DeAcido process](image)

The DeAcido process core consists of two phases esterification reaction, at the end of which the acid catalyst is removed by means of an easy decanting operation (Figures 25-26). At this stage, other polar components present in the oil (phospholipids, glycolipids, etc) are removed with the polar phase, obtaining deacidification and degumming in a single operation, allowing use of fats and oils of very poor quality as raw materials for FAME preparation.
Figure 25. First step of DeAcido process – fatty acid esterification

Figure 26. Second step of DeAcido process – triglycerides transesterification

The application of DeAcido process, beyond the overrun of the ethical aspects for the use of edible oils in not food industrial applications, also reduces the final price of these innovative products (Cl-FAME and SCI-FAME) for the fatting phase of the leather tanning process, as you can see from the Table 13.

Table 13. Final price of benchmark products and new products.

<table>
<thead>
<tr>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of C_{14}–C_{17} paraffin from oil</td>
<td>1.31 €/kg</td>
</tr>
<tr>
<td>Price* for CLOPARIN 44F (Chlorinated paraffin)</td>
<td>1.05 €/kg</td>
</tr>
<tr>
<td>Price* for CLOPARTEN Z (Sulfo-chlorinated paraffin)</td>
<td>1.35 €/kg</td>
</tr>
<tr>
<td>Cost** of palm kernel oil</td>
<td>1.42 €/kg</td>
</tr>
<tr>
<td>Estimated price for Chlorinated FAME from Palm kernel oil</td>
<td>1.12 €/kg</td>
</tr>
<tr>
<td>Estimated price for Sulfo-Chlorinated FAME from Palm kernel oil</td>
<td>1.23 €/kg</td>
</tr>
<tr>
<td>Estimated cost of FAME from acid fats with DeAcido process</td>
<td>0.95 €/kg</td>
</tr>
<tr>
<td>Estimated price for Chlorinated FAME from treated acid fats</td>
<td>0.91 €/kg</td>
</tr>
<tr>
<td>Estimated price for Sulfo-Chlorinat. FAME from treated acid fats</td>
<td>1.02 €/kg</td>
</tr>
</tbody>
</table>

* data from COLORTEX  
** data from GAMMA CHIMICA for Palmere M1218 PK


INESCOOP and COLORTEX have created 20 hide sample tanned with the new and innovative natural products fatting technique, the leather sample books of hides are produced during the semi-industrial and preindustrial demonstrations and he used full grain, split calf
hides and sheep skin with various finishing for different articles like shoes, leather goods, garment and upholstery. This Manual describes the fatliquoring procedure of leathers by using the natural products optimized under the LIFE ECOFATTING project. The manual contains a step by step description of the current industrial process. It also contains first a detailed description of the conventional leather fatliquoring process and afterwards, a detailed description of the environmentally friendly natural fatliquoring process.

The content of the Manual is structured as follows:

1. Introduction
2. Description of the tanning process
   3. Conventional leather fatliquoring process
      3.1. Scope and description of the process of leather fatliquoring
      3.2. Fatliquoring products: raw materials, characteristics and action on the leather
      3.3. Practice of fatliquoring with conventional products
      3.4. Problems in the fatliquoring operation and leather defects
      3.5. Environmental impact of the fatliquoring process
4. Environmentally friendly natural fatliquoring process
   4.1. Natural products developed: raw materials, obtaining process, characteristics and properties
   4.2. Practice of fatliquoring with alternative products: description, technical and environmental validation of the process and technical validation of leather.
5. Bibliography

The “Natural products fatting manual” is Annex. As scheduled, this action has been completed by 100%.

5.2 Dissemination actions

5.2.1 Objectives
All the project beneficiaries made sure that the ECOFATTING project gained maximum visibility at a European level. During the project life time various dissemination materials were produced and distributed in fairs, conferences, newsletters and so on. A logo was designed together with banners, brochures, gadgets and various other items which allowed for a full dissemination of the project aim and results. Several interviews and articles to the project beneficiaries were also broadcasted on TV and newspapers and a project website was created and published online within the second month of the project. In addition to dissemination activities among the general public, the project results were also the object of scientific publications and training courses and workshops especially aimed at Italian and Spanish tanneries.

The tight, fruitful cooperation among ECOFATTING beneficiaries gave very positive results, feasible in the practice and also in dissemination activities. The natural product developed in the ECOFATTING project for leather fatting and hide tanning was disseminated as a step forward towards the evolution of a tanning process in a “green”, environmental-oriented direction. This product was proved and disseminated to be indeed more performing than the currently used chemical agents and characterized by a higher biodegradability. Its use was also disseminated as advantageous in terms of waste water treatment and waste water disposal. All the beneficiaries were involved in the development and implementation of the following main ECOFATTING dissemination activities from the start of the project (01/01/2012) until the end of the project (31/12/2013):

- Development of the web site: ICCOMCNR registered, developed and updated the website http://www.pi.iccom.cnr.it/ecofatting/it/
- **Notice board:** ICCOMCNR produced 12 ECOFATTING notice boards, which were sent to all the partners and displayed in visible spots and accessible places to the public on the partners’ premises.

- **Dissemination material:** ICCOMCNR produced 2 banners (in Italian and in English), 1,000 brochures of the project (500 in Italian and 500 in English), 1,000 eco bags as project gadget and 2 roll ups (in Italian and in English), 10 posters, 3 ECOFATTING power point presentation (in English, Italian and Spanish) and specific dissemination materials for the project training courses and workshops

- **Events:** ECOFATTING project was presented to 25 events and fairs
- TV interviews, articles and press release: 4 TV interviews and 20 press articles
- 1 project video in English, Italian and Spanish

The target groups of the ECOFATTING dissemination activities and materials were:
- tannery and leather technicians and experts, technology transfer organisations managers, environmental Institutions, public authorities;
- public audience and consumers.

The following table summarises and compares for each project ACTION which dissemination activity and material was foreseen in the project and which was the final real results.

<table>
<thead>
<tr>
<th>Action</th>
<th>Name of the Action</th>
<th>Deadline</th>
<th>Expected results as for project</th>
<th>Results at month 24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action 12</td>
<td>Leather sample books</td>
<td>24 months</td>
<td>Preparation of 10 hide sample books</td>
<td>3 samples books with 20 hide</td>
</tr>
<tr>
<td>Action 13</td>
<td>Material preparation for workshops</td>
<td>24 months</td>
<td>Logo definition 1 banner 1000 brochures 1000 gadgets 1 roll up 1 project presentation</td>
<td>Logo definition 2 banner 1000 brochures 1000 eco bags as gadgets 2 roll up 3 project presentations</td>
</tr>
<tr>
<td>Action 14</td>
<td>Diffusion material preparation</td>
<td>24 months</td>
<td>10 notice boards 20 press articles 3 TV interviews</td>
<td>12 notice boards 4 TV interviews 17 general articles 3 technical articles</td>
</tr>
<tr>
<td>Action 15</td>
<td>Training course for Italian tanneries</td>
<td>24 months</td>
<td>25-50 technicians from tanneries trained in natural products fatting phase</td>
<td>50 technicians from tanneries trained in natural products fatting phase</td>
</tr>
<tr>
<td>Action 16</td>
<td>Training course for Spanish tanneries</td>
<td>24 months</td>
<td>25-50 technicians from tanneries trained in natural products fatting phase</td>
<td>50 technicians from tanneries trained in natural products fatting phase</td>
</tr>
<tr>
<td>Action 17</td>
<td>Demonstration workshop in Italy</td>
<td>24 months</td>
<td>25-50 Business people from tanneries and leather companies informed.</td>
<td>50 Business people from tanneries and leather companies</td>
</tr>
<tr>
<td>Action 18</td>
<td>Demonstration workshop in Spain</td>
<td>24 months</td>
<td>25-50 Business people from tanneries and leather companies informed.</td>
<td>50 Business people from tanneries and leather companies</td>
</tr>
<tr>
<td>Action 19</td>
<td>International fairs and other events</td>
<td>24 months</td>
<td>Participation at 20 events</td>
<td>Participation at 25 events</td>
</tr>
<tr>
<td>Action 20</td>
<td>Digital supports for international diffusion</td>
<td>24 months</td>
<td>100 copies of 1 project video in English, Italian and Spanish</td>
<td>Production of project video</td>
</tr>
<tr>
<td>Action 21</td>
<td>International</td>
<td>24 months</td>
<td>Project web site</td>
<td>Project web site updated</td>
</tr>
<tr>
<td>Action 22</td>
<td>After-LIFE Communication plan</td>
<td>24 months</td>
<td>After-LIFE Communication plan</td>
<td>After-LIFE Communication plan</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------------------------</td>
<td>-----------</td>
<td>-------------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>diffusion and dissemination</td>
<td>Clusters with 10 projects 10 posters</td>
<td>Clusters with 11 projects 10 posters</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.2.2 Dissemination: overview per activity

5.2.2.1 Action 12 Leather sample books of hides fatted with natural products.
COLORTEX produced 3 leather sample books: in Italian, in English and in Spanish with 20 ECOFATTING tanned leather samples (10 from INESCOP for shoes and 10 from COLORTEX for garment and auxiliaries)

5.2.2.2 Action 13 Material preparation for workshops
During the project lifetime, all beneficiaries prepared various dissemination materials to be used in fairs, conferences, newsletters, etc, in particular:
- Logo definition and design performed. An ECOFATTING logo was created for the project, which will be shown on all dissemination documents of the project.
- ICCOMCNR produced 1 banner in Italian and 1 banner in English
- ICCOMCNR produced 500 brochures of the project in Italian and 500 brochures in English
- ICCOMCNR produced 1,000 eco bags as project gadget
- ICCOMCNR produced 1 roll up in Italian and 1 roll up in English
- ICCOMCNR and INESCOP produced 10 posters
- ICCOMCNR produced an official ECOFATTING power point presentation in English and Italian to be used in events
- INESCOP produced an official ECOFATTING power point presentation in Spanish to be used in events
- COLORTEX and INESCOP produced specific dissemination materials for the project training courses and workshops
- ICCOMCNR produced 12 ECOFATTING Notice boards
- ENEA produced 1 project video in English, Italian and Spanish

The above mentioned materials are detailed in the ECOFATTING Deliverable related to Actions 13-22 and in the ECOFATTING Annex Dissemination activities.

5.2.2.3 Action 14 Diffusion material preparation
During the project lifetime ICCOMCNR created the structure of the project Notice board and produced 12 ECOFATTING Notice boards, which were sent to all the partners and displayed in visible spots and accessible places to the public on the partners’ premises. COLORTEX and INESCOP produced specific dissemination materials for the project training courses and workshops
In particular the following TV interviews and articles were produced:
- ICCOMCNR carried out three TV interviews with local TV agencies
- COLORTEX carried out one TV interview during the ECOMONDO fair
- ENEA produced 3 articles related to ENEA event for the 20th Anniversary of the LIFE Programme, Faenza, June 21st 2012: three press releases have been made by ENEA, two of which published into the ENEA official web site and one disseminated through mayor local newspapers.
- ICCOMCNR produced 2 general articles edited by Pisa local newspapers
- ENEA produced 1 general article edited by Sole 24ore on 28/10/2013
- From January to August 2013, INESCOP presented the project through 11 newsletters that are distributed in electronic and paper form to INESCOP’s member companies
- ICCOMCNR prepared a Technical Article in “Ars Tannery” (vol. 06 December 2013, pag 59-62) and in “Physical Chemistry Chemical Physics” (15, 2013, pag 14736-14747).

- INESCOP produced an article related to ECOFATTING participation at the Conference in Green Week Satellite events; Brussels (Belgium), 22nd May 2012
- INESCOP prepared a Technical Article in “Journal of AQEIC” (3rd trimester 2013)

The above mentioned materials are detailed in the ECOFATTING Deliverable related to Actions 14, 21 and in the ECOFATTING Annex Dissemination activities.

5.2.2.4 Action 15 Training course for Italian tanneries
A training course specifically aimed at tanning companies was carried out in COLORTEX premises on May 31st with the following program:
- Presentation of Life Program and ECOFATTING project.
- Description of the results of ECOFATTING obtained on the study of the interaction of leather proteins with chloroparaffins, chlorosulfonated paraffins and the developed natural products, CI-FAME SCI-FAME.
- Applicative processes and formulations for the production of leather products with CPs, SCP, CI-FAME, SCI-FAME: comparison and advantages of natural products.
- Demonstration of hides tanned/fatted with CPs, SCP, CI-FAME, SCI-FAME.
- Demonstration of environmental benefits of natural products.
- Demonstration and discussion of legislative developments
- Practical section with the demonstration of the application of the new process at a semi-industrial level, using a tanning pilot plant in COLORTEX.

The course brought together 30 technicians from the leather industry of the tannery district of Santa Croce sull'Arno.

The Italian training course is detailed in the ECOFATTING Annex Dissemination activities.

5.2.2.5 Action 16 Training course for Spanish tanneries
As planned, on 20th June 2013 the course “Tecnologías de engrase innovadoras mediante productos de origen natural” (Innovative fatliquoring technologies based on products of natural origin) was held in the premises of the INESCOP in Elda (Alicante). The course brought together 20 technicians from the leather industry and chemical suppliers. In this course different aspects related to the LIFE ECOFATTING project were presented, such as the project objectives and stages, the environmental impact assessment of the fatliquoring products commercially available (reference products) and the characteristics and properties of the fatliquoring products developed. Some leather samples were displayed, which had been fatliquored with different products, and their qualities were comparatively assessed.

The course ended with a lively round table, where the attendees actively participated and showed their interest in the qualities of the fatliquoring products developed. They also filled in a course assessment questionnaire.
The Spanish training course is detailed in the ECOFATTING Annex Dissemination activities.

5.2.2.6 Action 17 Demonstration workshop in Italy
A demonstration workshop dedicated to business and political people was held at COLORTEX premises on November 20th with the following program:
- Presentation of the Life Program
- Presentation of the ECOFATTING project.
- Presentation of the ECOFATTING innovative use of natural products.
- Exhibition of the ECOFATTING products
The course brought together 50 managers and leather experts from the leather industry of the tannery district of Santa Croce sull'Arno.
The Italian workshop is detailed in the ECOFATTING Annex Dissemination activities.

5.2.2.7 Action 18 Demonstration workshop in Spain
As planned, on 7th November 2013 the workshop “Tecnologías limpias en curtidos” (Clean tanning technologies) was held in the premises of the Confederación Empresarial Valenciana (CEV) in Valencia (Spain). The workshop brought together 36 technicians from the leather industry and chemical suppliers. In this workshop different aspects related to the LIFE ECOFATTING project were presented, such as the project objectives and stages, the environmental impact assessment of the fatliquoring products commercially available (reference products) and the characteristics and properties of the fatliquoring products developed.
The workshop ended with a lively round table, where the attendees actively participated and showed their interest in the qualities of the fatliquoring products developed.
The Spanish workshop is detailed in the ECOFATTING Annex Dissemination activities.

5.2.2.8 Action 19 Internationals fairs and other events
In this project period, the following activities were carried out related to this Action 19:
- ECOFATTING power point and video presentations at the Italian Celebration Day for the 20th Anniversary of the LIFE Programme, Brescia, May 25th, 2012
- ECOFATTING power point presentation at “XXII Settimana della Cultura Scientifica a Tecnologica” in Faenza, Aprile 18th, 2012
- ICCOM-CNR presented ECOFATTING in seven international meetings:
  - XXI National Meeting of Italian Society of Pure and Applied Biophysics (SIBPA), 17-20 September 2012;
  - XXIII National Meeting of Analytical Chemistry, Italian Chemical Society, La Biodola (Elba), 16-20 September 2012: the description of part of the results of Action 1 were presented in a published abstract and in a poster.
  - Po.Te.Co. (Polo tecnologico conciario) in Castelfranco di sotto (PI), 10/12/2012
  - XXXVIII Colloquium Spectroscopicum Internationale in Tromsø, Norway, June 16 – 20, 2013
  - XXIV Congresso della Divisione di Chimica Analitica 15-19 Settembre 2013 in Sestri Levante (GE)
  - ECOCITY November 21-24, 2013 in Pisa
  - ECOMONDO fair in November 5-8, 2013 in Rimini
ENEA presented a poster in the 3rd International Conference on Industrial and Hazardous Waste Management which was held in Chania (Crete, GR) on September 12-14th, 2012.

ENEA presented the project in a specific stand in the ECOMONDO fair in November 5-8, 2013 in Rimini

COLORTEX presented the project in the LINEA PELLE fair in Bologna (Italy), 8th - 10th October 2013.

INESCOP presented the project in 12 different national and international fairs listed below:

- 12th Edition of Green Week, Brussels (Belgium), 22nd – 25th May 2012
- Conference in Green Week Satellite events; “Regional responses to the EU2020 on water. Lessons learned through European projects”, FCVRE, Brussels (Belgium), 22nd May 2012.
- 1st Water, Waste and Energy Management, Salamanca (Spain), 23rd – 25th May 2012
- Industrial Technologies Congress, 2012, Aarhus (Denmark), 19th – 21st June 2012
- 18th Congress of the Latin American Federation of Leather Chemists and Technologists, Montevideo (Uruguay), 9th - 11th October 2012.
- 29th Edition of the International Footwear Fair, FUTURMODA, Alicante (Spain), 17th – 18th April de 2013.
- 62nd Congress of the Spanish Leather Chemists Association AQEIC; Lorca – Murcia (Spain), 10th – 11th May 2013
- LIFE+ Networking Event, Valencia (Spain), 14th May 2013
- LINEA PELLE fair in Bologna (Italy), 8th - 10th October 2013

The participation at the project events is detailed in the ECOFATTING Annex Dissemination activities.

5.2.2.9 Action 20 Digital supports for international diffusions

ENEA, as ECOFATTING video project responsible, selected an external service video company expert for the collection and mixing of each associated beneficiary activities video and production of the global ECOFATTING video.

The external service video company contacted each associated beneficiary and produced the ECOFATTING video with:

- ICCOMCNR and ENEA: laboratory activities videos
- SERICHIM: natural products production videos
- COLORTEX and INESCOP: ECOFATTING leather and products production videos

The ECOFATTING video is showed in the DVDs representing the Deliverable related to ECOFATTING Action 20, which we are sending as attachment to the Final Report.

5.2.2.10 Action 21 International diffusion and dissemination

- ECOFATTING website in Italian, English and Spanish: www.pi.iccom.cnr.it/eco fatting/it
- ICCOMCNR produced 2 roll up
ICCOMCNR produced 10 posters
ICCOMCNR produced an official ECOFATTING power point presentation in English and Italian to be used in events
INESCOP produced an official ECOFATTING power point presentation in Spanish to be used in events
17 general articles
3 technical articles
ICCOMCNR carried out three TV interviews with local TV agencies
COLORTEX carried out one TV interview during the ECOMONDO fair
Cluster with 11 projects: OXATAN, SHOELAW, PODEBA, SOREME, BioNaD, CLEANSED, After-Cu, MICROTAN, CO2SHOE, SHOEBAT and BIOREM (LIFE 09-10-11-12 projects)
The above mentioned diffusion material and activities are detailed in the ECOFATTING Annex Dissemination activities.

5.2.2.11 Action 22 After-LIFE Communication Plan
ICCOMCNR, with the support of all the partners, has produced the “After-LIFE Communication Plan” at the end of the project

5.3 Evaluation of Project Implementation
The project coordination actions needed daily work to maintain a permanent flow of action with the aim of achieving the objectives set. The actions carried out were:
- Preparation of the Partnership Agreement and relative Addendum
- 4 Coordination meetings:
  - Organisation of different meetings between some partners in order to plan and monitor the project technical activities
  - Continuous contact between all project partners for monitoring project activities
  - General actions and activities for the coordination of the project.
  - Management of the financial aspects of the project.
  - Monthly reports to the LIFE external team monitor on the evolution of the project.
- ICCOMCNR, as project coordinator, prepared and sent a monthly indication of operative activities to be done to all the partners
- ICCOMCNR, as project coordinator, prepared and sent a monthly summary of the project activities carried out to the TIMESIS monitor and to all the partners.

The following table compares through quantitative and qualitative information the results achieved at the end of the ECOFATTING project against the objectives of the proposal:

<table>
<thead>
<tr>
<th>Action</th>
<th>Foreseen in the proposal</th>
<th>Achieved</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action 1</td>
<td>Study on the different fatliquoring agents currently used in the EU tanneries</td>
<td>Interaction evaluation</td>
<td>More than expected</td>
</tr>
<tr>
<td>Action 2</td>
<td>Study of the environmental impact of the different fatliquoring agents most used by European tanneries</td>
<td>Study performed</td>
<td>In line</td>
</tr>
<tr>
<td>Action 3</td>
<td>Definition and evaluation of natural products as substitutes for CPs</td>
<td>Definition and evaluation of natural products as substitutes for CPs</td>
<td>In line</td>
</tr>
<tr>
<td>Action</td>
<td>Description</td>
<td>Description</td>
<td>Result</td>
</tr>
<tr>
<td>----------</td>
<td>------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Action 4</td>
<td>Production of standard samples by using CPs; laboratory production of innovative samples by using natural products</td>
<td>Production of standard samples by using CPs; laboratory production of innovative samples by using natural products</td>
<td>In line</td>
</tr>
<tr>
<td>Action 5</td>
<td>sheep/goat skins leathers tanned with the use of natural products in the fatting phase; analysis of the environmental impact from the hide tanning process by using natural products instead of CPs in the fatting phase</td>
<td>sheep/goat skins leathers tanned with the use of natural products in the fatting phase; analysis of the environmental impact from the hide tanning process by using natural products instead of CPs in the fatting phase</td>
<td>In line</td>
</tr>
<tr>
<td>Action 6</td>
<td>sheep/goat skins leathers tanned with the use of natural products in the fatting phase, bovine skins leathers tanned with the use of natural products in the fatting phase, analysis of the environmental impact from the hide tanning process by using natural products instead of CPs in the fatting phase</td>
<td>sheep/goat skins leathers tanned with the use of natural products in the fatting phase, bovine skins leathers tanned with the use of natural products in the fatting phase, analysis of the environmental impact from the hide tanning process by using natural products instead of CPs in the fatting phase</td>
<td>In line</td>
</tr>
<tr>
<td>Action 7</td>
<td>100 leather products elaborated with natural products fatted leathers, -Production of more environmentally friendly leather products, that complies with the European Eco-label criteria</td>
<td>100 leather products elaborated with natural products fatted leathers, -Production of more environmentally friendly leather products, that complies with the European Eco-label criteria</td>
<td>More than expected-PODEBA networking</td>
</tr>
<tr>
<td>Action 8</td>
<td>Proof of environmental benefits</td>
<td>Proof of environmental benefits-LCA study</td>
<td>More than expected</td>
</tr>
<tr>
<td>Action 9</td>
<td>Leather products production that complies with quality standards necessary for leather in terms of resistance, tensile strength, elongation percentage, contraction temperature, thickness, feel, fullness, yellowing, creases, grain strength.</td>
<td>Physical validations of hides and related report</td>
<td>In line</td>
</tr>
<tr>
<td>Action 10</td>
<td>Proof of quality and economic viability</td>
<td>Proof of quality and economic viability</td>
<td>In line</td>
</tr>
<tr>
<td>Action 11</td>
<td>Manual about new natural products fatting technique in 1,000 copies of the project manual by means of a DVD</td>
<td></td>
<td>In line</td>
</tr>
<tr>
<td>Action</td>
<td>Description</td>
<td>Result</td>
<td>Notes</td>
</tr>
<tr>
<td>----------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-------------------------</td>
<td>----------------------------</td>
</tr>
<tr>
<td>Action 12</td>
<td>Preparation of 10 hide sample books</td>
<td>3 samples books with 20 hide</td>
<td>More than expected</td>
</tr>
<tr>
<td>Action 13</td>
<td>Logo definition 1 banner 1000 brochures 1000 gadgets 1 roll up 1 project presentation</td>
<td>Logo definition 2 banner 1000 brochures 1000 eco bags as gadgets 2 roll up 3 project presentations</td>
<td>More than expected</td>
</tr>
<tr>
<td>Action 14</td>
<td>10 notice boards 20 press articles 3 TV interviews</td>
<td>12 notice boards 4 TV interviews 17 general articles 3 technical articles</td>
<td>More than expected</td>
</tr>
<tr>
<td>Action 15</td>
<td>25-50 technicians from tanneries trained in natural products fatting phase</td>
<td>50 technicians from tanneries trained in natural products fatting phase</td>
<td>In line</td>
</tr>
<tr>
<td>Action 16</td>
<td>25-50 technicians from tanneries trained in natural products fatting phase</td>
<td>50 technicians from tanneries trained in natural products fatting phase</td>
<td>In line</td>
</tr>
<tr>
<td>Action 17</td>
<td>25-50 Business people from tanneries and leather companies informed.</td>
<td>50 Business people from tanneries and leather companies</td>
<td>In line</td>
</tr>
<tr>
<td>Action 18</td>
<td>25-50 Business people from tanneries and leather companies informed.</td>
<td>50 Business people from tanneries and leather companies</td>
<td>In line</td>
</tr>
<tr>
<td>Action 19</td>
<td>Participation at 20 events</td>
<td>Participation at 25 events</td>
<td>More than expected</td>
</tr>
<tr>
<td>Action 20</td>
<td>100 copies of 1 project video in English, Italian and Spanish</td>
<td>Production of project video</td>
<td>In line</td>
</tr>
<tr>
<td>Action 21</td>
<td>Project web siteClusters with 10 projects 10 posters</td>
<td>Project web site updated Clusters with 11 projects 10 posters</td>
<td>More than expected</td>
</tr>
<tr>
<td>Action 22</td>
<td>After-LIFE Communication plan</td>
<td>After-LIFE Communication plan</td>
<td>In line</td>
</tr>
<tr>
<td>Action 23</td>
<td>Project management</td>
<td>Continuous contact between all project partners and project meetings</td>
<td>Great beneficiaries collaboration</td>
</tr>
<tr>
<td>Action 24</td>
<td>Project monitoring</td>
<td>monthly indication of operative activities and monthly summary of the project activities</td>
<td>Great help from monitoring team</td>
</tr>
<tr>
<td>Action 25</td>
<td>Audit Report</td>
<td>Audit Report</td>
<td>In line</td>
</tr>
</tbody>
</table>

It is clearly evident from the above table that the actual dissemination results are better and more numerous than was expected in the ECOFATTING proposal.
5.4 Analysis of long-term benefits - LCA

To remain competitive in the global market place, European leather producers must exploit more efficiently their raw materials and avoid wasting collagenous material (hides and skins) that constitutes valuable raw material for other industries and agriculture. Wasting raw materials creates waste which has high adverse environmental and cost implications. By-products should be either reused/recycled or converted into new, higher value products.

Accordingly, EU tanners are adjusting their production towards higher quality output and high fashion content leathers. Modernisation of the sector also concerns all the investments made by EU tanners in environmental protection, waste reduction, recycling, recuperation of secondary raw materials, etc. The impact of environmental regulation on the leather tanning industry is considerable. The industry estimates that environmental protection costs amount to 5% of all operational costs.

Europe is an important player in the international leather trade. With some 25% of the world's leather production and one of the largest and most dynamic consumer markets for leather articles, Europe stands out as the leading force in international business circles in relation to leather and tanning. With a turnover of nearly € 8 billion, over 3,000 companies and some 50,000 people directly employed in the sector, Europe's tanneries demonstrate their competitiveness on the global market. Their products are renowned and appreciated by manufacturers worldwide for their quality and fashionable designs. European leathers are exported all over the world to satisfy the highest standards, the most stringent ecological regulations and the increasing expectations of quality aware consumers.

Tanners in Europe have a long tradition of producing all kinds of leather, from bovine and calf leather to sheep and goat leather, from sole and exotic specialities to double-face garment leather. Their expertise contributes to the success of leading footwear, garment, furniture and leather goods manufacturers. This solid experience and the outstanding know-how of European tanners and dressers is displayed at major international fairs. All this explains the continuously strong demand for their products on international markets.

In the last decade, European finished leather exports to other regions in the world have experienced an extraordinary development. Manufacturers in new and emerging markets are particularly keen to develop trade relations with European tanners and to work closely with them. Small and medium sized companies predominate in the European tanning sector. The consequent flexibility, adaptability and the quick response to demand constitutes one of the industry's most important assets. Larger companies, however, excel thanks to their capacity to be at the forefront of technological developments and to constitute reliable partners in global business activities. Technological leadership, fashion, design, quality, excellent raw materials and the sense of service to the customer are all factors contributing to the strength of European tanners. Continuing modernisation combined with investment in training, environmental infrastructure, R&D and export promotion allows the industry's operators to look to the future with confidence. It is fundamental to provide these industries with innovative and eco-friendlier leathers that meet the European quality standards. In this sense, leather industries will be going for a type of leathers that allow for the eco-design of products, which is currently more and more demanded by European end-users.

The leather sector is a “heavy impact” one and a large consumer of sources: for 1 ton of initial hides/skins more than 400 kg of reagents/additives are needed. The implementation of ECOFATTING project is a strategy to prevent waste production, to save resources and to reduce environmental impact. The production of chlorinate/sulpho-chlorinated Palmkernel oil Fatty Acid Methyl Ester compounds in ECOFATTING contributes to the reduction of energy consumption and resources. In particular, the potential impact on the category of abiotic resources (fossil) is about half of the corresponding CLOPARIN 44F and CHLOPARTEN Z,
while the contribution to the Global Warming Potential and to the Photochemical Ozone Creation Potential are about 10% and 40% less, respectively.

The new fatliquoring molecules were found more biodegradable than benchmark product and 40% increase in biodegradability (BOD/COD) was also found at in the fat-liquoring residual baths at industrial level, in an “industrial” tannery. This allows to better manage the wastewater treatment. This is also a direct response to bioaccumulation, since bioaccumulation is by definition connected with non-biodegradability. Chloroparaffins are indeed persistent agents which are not easily degraded by natural mechanisms. They are bioaccumulative substances which accumulate mainly in aquatic animal tissues, and enzymatic disrupters which alter the hormonal system of living beings. Excessive exposure to CPs may affect the kidney, liver and thyroid gland, and may cause cancer, especially the short chain CPs (SCCPs, with chain legth up to 13).

In the EU, the use of SCCPs is restricted in REACH. Regulation (EC) 552/2009, amending ANNEX XVII of REACH, prohibits SCCPs in certain processes and consumer products (Commission Regulation (EC) 552/2009 of 22 June 2009 amending Regulation (EC) No 1907/2006 of the European Parliament and of the Council on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) as regards Annex XV; MORE (http://product-industries-research.hktdc.com/business-news/article/Gifts-Houseware/Usage-of-Short-Chain-Chlorinated-Paraffins-SCCPs/pls/en/1/1X000000/1X06L9ZA.htm#.1). The substance is also listed on the ‘Candidate List’ and has been recommended by the European Chemical Agency (ECHA) for inclusion on ANNEX XIV of REACH (list of substances subject to authorization). Its inclusion on the Candidate List may have immediate obligations to communicate in the supply chain. Highlights on these are summarized in Table 1 (http://product-industries-research.hktdc.com/business-news/article/Gifts-Houseware/Usage-of-Short-Chain-Chlorinated-Paraffins-SCCPs/pls/en/1/1X000000/1X06L9ZA.htm#sthash.0uUr7HRv.dpuf).

In ECOFATTING products it was not possible to avoid chlorination and sulpho-clorination, because of the mechanisms of fattening with the need to fill the voids inside pelts and the need to connect different fattening compounds layers among fibers, therefore via Cl and S bonds.

Taking into account that a chlorinated-sulphochlorinated product use of 1,8% w/w respect initial tons of hides/skins (according to Colortex formulations) and for Italy a figure of 500.000 t/y (17% of world leather production), it is possible to assess the prevention of 3.000-5.000 t/year of chloroparaffins products (30-50% of Italian share).

ECOFATTING, by developing new materials substituting the use of fossil-based ones, contributes to the objective of the resource efficient flagship initiative (COM 2011 (21)). In particular, within the flagship initiative, the Roadmap to a Resource Efficient Europe (COM(2011) 571) outlines how we can transform Europe's economy into a sustainable one by 2050, proposing ways to increase resource productivity and decouple economic growth from resource use and its environmental impact. Among the initiatives, the following is highlighted as relevant for ECOFATTING: “Focus Union research funding (EU Horizon 2020) on key resource efficiency objectives, supporting innovative solutions for environmentally friendly material extraction and green chemistry, among others. Moreover, as anticipated in the Resource Efficiency Roadmap, the European Commission, with the Recommendation of 9 April 2013 on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations, establish a common methodological approach to enable Member States and the private sector to assess, display and benchmark the environmental performance of products, services and companies based on a comprehensive assessment of environmental impacts over the life-cycle. Pilot tests have been launched, and among the 14 presently ongoing, a pilot test (guided by COTANCE - Confédération des Associations Nationales de la Communauté Européenne) is devoted to
“leather”. The ECOFATTING project represents an important contribution to this initiative, especially in setting up Product Environmental Footprint Category Rules for the sector “leather”.

In addition, it is important to highlight that the development of ECOFATTING project will support the application of the Environmental Technologies Action Plan (ETAP), whose objective is to further environmental technologies to improve the environment and European competitiveness supporting eco-friendly technologies since they are good for business, reduce pressure on the environment and can create new jobs. ETAP has among its high-priority actions getting from research to markets actions improving the innovation process and moving invention from laboratories to the market, and improving market conditions aiming at encouraging the market uptake of environmental technologies. Therefore, ETAP support the promotion of environmental technologies that has a great potential to improve the environment as well as the eco-innovation because both provide many benefits for business by fostering innovation, cutting production costs, creating jobs, reducing pressures on the environment and encouraging competitiveness.

Furthermore, as evidenced in Action 10, the project has focused on the substitution of chloroparaffin (paraffin backbone) in chlorinated FAME (fatty acid methyl esters as backbone) with optimum results inside fatliquoring compound. This has indicated/evidenced the possibility to exploit other source of FA, such as animal by-products.

Economical assessment and viability can be carried out for the different subjects of the production chain:

- Producer of chlorinated and sulpho-chlorinated palmkernel oil fattening products;
- Tannery (end user),
- Producer of Leather goods.

Economical assessment can be related to 1 ton of initial hide/skin or a ton of wet blue leather, which represents about 60% of initial weight (data from Colortex). In this report 1t WB (wet Blue leather) is considered as reference unit.

For tanneries, the economic changes can be connected to:

- changes in fatliquoring compound costs, which are resumed in Table 23;
- changes in fatliquoring residual bath and therefore in wastewater treatment costs.

Therefore, economic viability results for:

- use of Sulpho Chlorinated Palmkernel FAME (instead of CLOPARTEN Z),
- use of Chlorinated Palmkernel FAME (instead of CLOPARIN 44F),

taking into account previous assumptions and prices.

Economic benefits could become more important with a scale change in chloruration and sulpho-chloruration plants, which could afford lower production prices.

About social aspects, analysing the ECOFATTING results we can presume that:

1. there are no changes in plants, tanning process and no changes in jobs (number and mansion), nor additional resources are required;
2. there could be an expansion in an “ecofriendly market”, with leather treated with more natural products and with a higher social value and price;
3. the biodegradability tests on fatliquored leathers showed a significant improvement by natural products compared to synthetic ones, which implies a lower impact of the waste generated in the tanning process;
4. better use of renewable resources from vegetables, saving limited resources, from oil.

An indicator related to the process-energy of the raw materials production (palmkernel oil and paraffin) was evaluated; an energy reduction of more than 90% was observed for the production of natural based products, as detailed in attachment in the Deliverable related to Action10.
As far as concerns long term economic benefits, it is possible to save about 150.000 euro/y in Italy and the 300.000 €/y in Europe only with this only product substitution. This figure can 4 times multiply for worldwide leather production, because Europe represent about 25% of leather trade, as detailed in attachment in the Deliverable related to Action10.

The ECOFATTING technical application has been demonstrated at pre-industrial scale; this technology is potentially “ready for the market” and its transferability to industrial scale is connected to palmkernel oil chlorination industrial production, not for their use because there are no changes in fatliquoring compound use and operating in tanning cycle.

Replicability and transferability directly, as soon the eco-fatliquoring products are available. This could diffuse in Italian leather districts by Colortex and shoe section in Spain thanks to INESCOP Associated (Spanish and Italian market represent almost 90% of EU market); it could spread to international market (Chinese, Indian) market as an innovative proposal to jump “suspected” chloroparaffins also in the range 14-17. Economical viability, in particular for sulpho-Chlorinated palmkernel oil methyl esters, can push the introduction of the proposed products for tanneries, combining with ecofriendly lines.

In the framework of the networking action of Life+ program, ECOFATTING was strictly linked to Life10 ENV/IT/335 PODEBA project, which is related to the same sector of tanning. PODEBA demonstrates indeed the use of poultry processed with a specific technology in the bathing phase of the tanning process. ECOFATTING-PODEBA network represents a fundamental integration for the production of eco-friendly, final leather goods. The integrated use of “ecofriendly” products and technology for different phases of tanning cycle could create a market line of “more ecofriendly” and quality leather products with higher prices and wider spreading.

Best practice for fatliquoring phase have been used by beneficiaries for project development, in fact both Colortex and Inescop used their best receipt; the project aim was to substitute chloroparaffins based fatliquoring compounds with Palmkernel oil FAME based (from renewable sources and with lower environmental impact) without changing operating and best practice, in order to make easy their placing in the market and their use in handcraft and industrial application. In this way Colortex could propose and sell fat-liquoring compound containing the new natural products. Preliminary results obtained in the technical demonstration actions of ECOFATTING suggest that also not chlorurated fatty acid methyl esters (FAME) interact with leather proteins and may be potential not-chlorurated compounds for fatting process.

When the employment of CPs and SCPs will be restricted by legislation (it already occurred for short chain CPs and SCPs), suitable natural substitutes found in ECOFATTING process i) will preserve the production process of fat liquorng agents, ii) the facilities for their production are the same used for the production of paraffin oil derivates, thus no additional resources are required, iii) employment capacity is preserved, iv) their applicability can be extended to other technological area such as inks, paints or additives for plastics (i.e. all other fields of application of chlorine and sulfocloroparaffine from oil).

Last but not least, the finite leather products (bags, wallets, shoes, pillows) produced after the PODEBA bathing process and fatted with the new natural molecules developed in ECOFATTING have a higher aesthetical profile (touch, softness, resistance and fullness).

As already reported, the use of vegetable oils is common to the food industry, as alternative fuel and in other industrial applications, thus it presents some criticisms from the ethical point of view. As shown in the cost analysis the actual, attractive benefits in terms of price of chlorinated natural products become from the production of natural products from FAME coming from waste vegetable or animal fats, following the DeAcido technology of SERICHIM. The use of “waste materials” that have to be disposed if not reintegrated into the production cycle, has the double advantage of i) not affecting the natural food resources and ii) the use of waste material like fat from fleshing, which comes itself from tannery processes.
Thus, these fats would be available in the tannery area, without import materials from regions like Asia to European plants.

A manifestation of interest from SMITZOOON (http://www.smitzoon.nl/272/leather-chemicals.htm) a leather company from Netherland and from COLORTEX itself for the employment of the new ECOFATTING products suggests a possible success of the project in terms of market benefits.

It will be deeply considered the possibility for applying CIP Eco-Innovation Program as the reasonable next step for a good market application of such an eco-innovative solution.

The study pointed out that there are not clearly dominant results in favour of natural-based products or of paraffin-based ones. In fact, on the one hand, both for the chlorine- and sulphochlorine-based compounds, the natural products perform better in the environmental impact categories driven by energy, such as: Abiotic Depletion (fossil), Global Warming Potential, Photochemical ozone Creation Potential. This is because the production of petroleum-based products involve high quantities of fossil fuels. However – with the exception of the category Abiotic Depletion (fossil) - the differences between the compounds are small, and in both cases, the relevant process is represented by the chlorine production. Thus, further efforts should be spent on optimising the amount of chlorine necessary in the production, as this would drastically decrease the environmental profile of all the impact categories.

Limiting the analysis to the energy necessary for the production process of the main component of chlorinated- and sulpho-chlorinated based compounds, and thus to Palm kernel oil for Cl-FAME and Cl-SFAME, and paraffin for CLOPARIN 44F and CHLOPARTEN Z, the results pointed out that the production of paraffins is notably more energy intensive than that of palmkernel oil.

However, on the other hand, the natural-based product present less favourable environmental profile in relation to the categories of toxicity, and this is due to the cultivation of palm oil.

The results highlight that the choice of using natural products instead of paraffin-based ones, do not necessarily results in an overall improvements of the potential environmental impact of the process, as trade-offs exist among the impact categories. However, in order to further support the choice of natural-based products instead of the paraffin-based ones, it is suggested to perform a broader analysis, in which also market effects are taken into consideration. In particular, it would be necessary to perform a scenario analysis, considering the following aspects:

- the time horizon, so as to analyse the consequences of introducing natural-based products for the fatting phase into the market in the long term;

- the scale effects, i.e. the implementation of the ECOFATTING process at different scale, considering the displacement/replacement effects that might occur when using palmkernel oil, presently used for a variety of applications.

Thus, an analysis of future development scenarios, in which future probable changes both in technology and in the market are considered, would increase the knowledge about the system, in terms of its interaction with the socio-economic context.
7.1 Administrative annexes
The ECOFATTING Partnership agreement was already sent as attachment of the Inception Report.

7.2 Technical annexes
In attachment the following Deliverables foreseen in this project period:

- Action 5: Semi-industrial level
- Action 6: Pre-industrial level
- Action 7-8: Environmental demonstration
- Action 10: Study of technical-economic viability
- Action 20: Videos (in a DVD format)
- Action 14, 21: Articles and press releases
- Action 13-22: Dissemination material
- Action 23: The Layman's report in English and Italian languages
- Action 23: The Layman's report in English and Spanish languages
- Action 23: After-LIFE Communication Plan in English, Italian and Spanish languages
- Action 25: Audit report

In addition in attachment the following technical document:

- ECOFATTING manual related to Action 11

7.3 Dissemination annexes
In attachment the report "ECOFATTING Annex dissemination activities"

7.3.1 Layman's report
In attachment as Deliverable of Action 23:

- The Layman's report in English and Italian languages
- The Layman's report in English and Spanish languages

7.3.2 After-LIFE Communication plan
In attachment as Deliverable of Action 23:

- The After-LIFE Communication plan in English, Italian and Spanish languages

7.3.3 Other dissemination annexes
In attachment:

- A CD with all the photographs produced during the project
- A project brochure
- A DVD with the project videos as Deliverable of Action 20

7.4 Final table of indicators
In attachment the final outcome indicators’ tables