BIOCOPAC Plus

SUSTAINABLE BIO-BASED COATING FROM TOMATO PROCESSING BY-PRODUCTS FOR FOOD METAL PACKAGING

BIOCOPACPLUS is a project funded through "Life+ 2013 Environment Policy and Governance". The main objective is building a pilot plant to produce a bio-lacquer from tomato processing waste. Cutin, an element contained in tomato skin, is the substance used to formulate the eco-sustainable lacquer for coating food-grade metal cans.

The BiocopacPlus project has been developed by the following bodies:

SSICA
STAZIONE SPERIMENTALE PER L'INDUSTRIA DELLE CONSERVE ALIMENTARI

CFT
LEADERS INNOVATE.

Azienda Agricola Chiesa Virginio

Salchi
SALCHI METALCOAT

TABLE OF CONTENTS

01 Project Scope & Objectives

The main objective of this LIFE Project is to prove and demonstrate on a semi-industrial scale the viability of an innovative technology for the production of a bio-lacquer to be used as coating for food metal cans.
Using renewable sources like **industrial tomato processing by-products, BiocopaPlus offers** an innovative, effective, environment-friendly alternative to the oil-based lacquers usually applied on the metal packaging surface to improve its corrosion resistance.
The project deals with the enhancement of tomato skins by offering alternative strategies for the use and minimization of waste in accordance with Directive 2008/98/EC. Thus as the **new bio-based lacquer comes from natural products**, BiocopacPlus **reduces the risk of migration of dangerous synthesized substances and off-flavours and improves the recyclability of the packaging**. The project is industry driven and focused on demonstration activities aimed at proving the technical feasibility and effectiveness of cutin extraction and production systems.

THE INITIAL SUBSTANCE IS CUTIN, A COMPONENT OF THE CUTICLE OF TOMATO SKIN AND A NATURAL POLYESTER-LIKE POLYMER.

The general objectives have been achieved through different specific objectives, each one contributing to the success of the project in its totality:

- To **design and scale-up a prototype plant for the cutin extraction process** to obtain a cutin with constant physical-chemical properties and suitable for the bio-resin formulation;
- To **optimize the prototype plant in terms of resource efficiency and saving** (water, energy, emissions) and of economic sustainability, by using automated, low maintenance technologies;
- To **develop and produce a bio-resin** suitable to formulate water-based and solvent-based lacquers;
- To **formulate lacquers suitable to be applied on standard industrial lines** without any changes needed;
- To **produce bio-lacquers suitable for contact with food** that differ in terms of composition and aggressiveness;
- To **perform the LCA analysis of the new eco-cans** for demonstrating their sustainability from production to disposal;
- To **analyze the economic potential of the exhausted skins** (e.g. for bio-energy applications) and assess environmental sustainability.

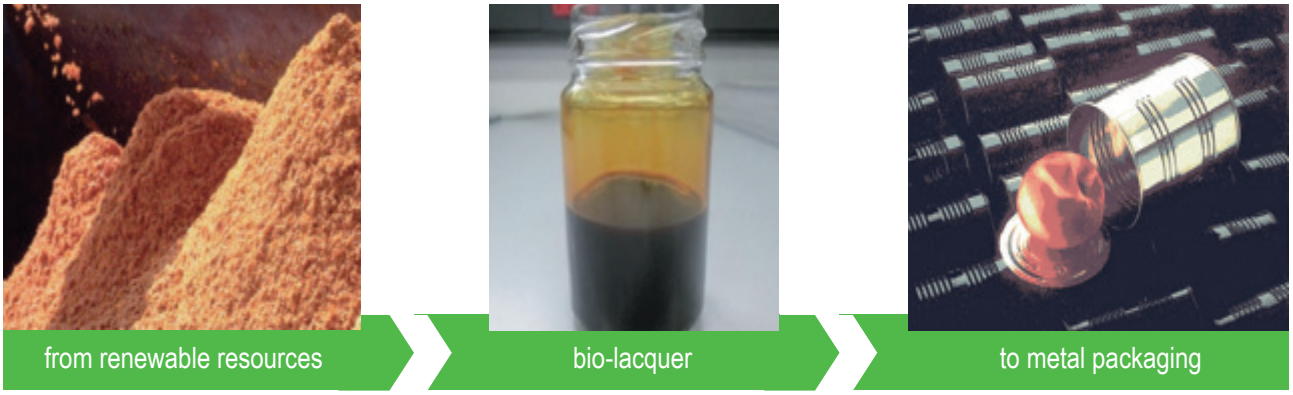
02 Problem and Background Information

The bio-lacquer is an interesting alternative to organic petrol-based coatings for food contact metal packaging as it complies with safety and sustainability standards, and meets new consumer demands.

Today's society, in which there is a strong demand for high nutritional standards, is characterized by rising costs and often decreasing availability of raw materials together with growing concern for environmental pollution.

The food industry produces large volumes of by-products resulting from the manufacturing, preparation and consumption of food. These by-products pose increasing disposal and potentially serious pollution problems and represent a loss of valuable biomass and nutrients. Consequently there is a considerable emphasis on the recovery, recycling and upgrading of by-products.

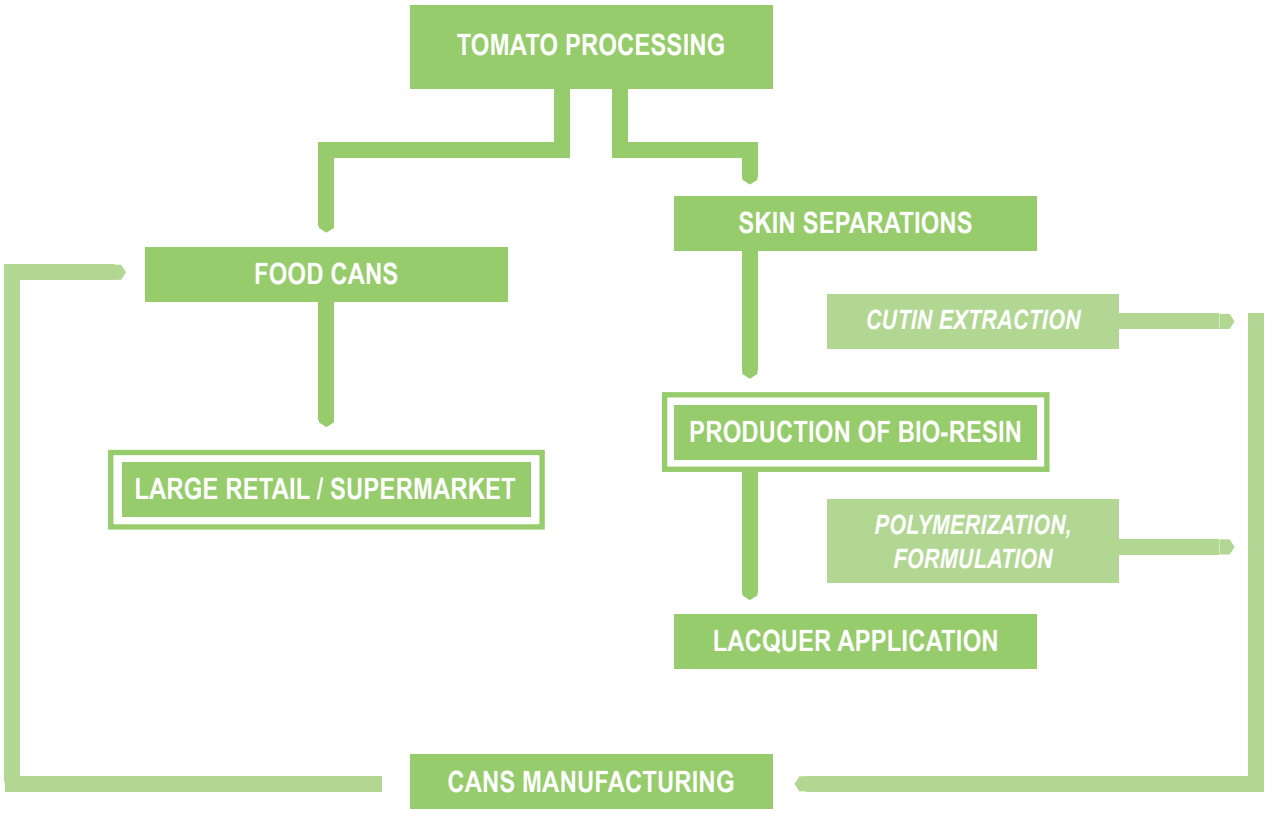
In Europe, the packaging market is growing year after year and, specifically, food packaging accounts for 65% of the total packaging market, which is worth approximately 8 million euro, and of which metal packaging is 1.9M tons. Tomato production in the EU-28 was estimated to amount to 17.9 million tons in 2016, i.e. each year the EU-28 generates more than 300,000 tons of solid tomato residues (skins and seeds).
BiocopacPlus identifies a new and different possibility to exploit processing tomato wastes for higher-value and useful products, **using non-conventional carbon sources to produce bio-lacquers rather than fossil sources.**



In line with the greater attention paid to hygiene/health and the environment, synthetic lacquers have been the subject of several cases of alert. The problem of the migration of residues of polymerization, monomers and oligomers, as well as additives, has given rise to press campaigns and has raised doubts and uncertainty in **consumers**, with consequent damage to the image of the can-making industry.
Recently great attention has been dedicated to BPA, which has been confirmed as having disruptive effects on the endocrine system.
Even if not imposed by the law, many food industries and large-scale retailers order BPA-free packaging to their suppliers.

03 How the BIOCOPAPLUS Consortium tackled the problem?

BIOCOPACPLUS promotes the solution of the above mentioned problems by carrying out a demonstration project that, by means of an innovative technology, aims at obtaining a cutin-based lacquer from processing tomato by-products, to be employed in the manufacture of metal packaging, which enhances industrial agro-waste and does not contain BPA.



METHODOLOGY

The original idea of the project is based on an old patent developed by SSICA in the 1940s and on the work performed in a previous FP7 BIOCOPAC project, from which the method of extraction was taken and then developed in laboratory. An international patent (WO2015028299A1) was obtained. The method allowed a monomer/oligomer product to be obtained, of which the principal component is 10,16 dihydroxyhexadecanoic acid, with characteristics suitable for preparing the bio-resin and the subsequent lacquer.
Thanks to these positive results, BiocopacPlus realized a pilot plant for cutin extraction to scale up the method from a laboratory level to a semi-industrial level.
The scale up strategy consisted in changing the laboratory experimental conditions to obtain cutin with the same performances obtained in laboratory.
The project was implemented through 12 actions: A1, B1, B2, B3, B4, B5, B6, C1, C2, D1, E1, E2.

EVALUATION OF THE TOMATO WASTE AND ITS POTENTIAL RE-USE

An economic study on tomato processing companies and on the biological and chemical safety of tomato waste was carried out. The study analyzed data subdividing it into two main geographic macro-areas: Southern and Northern-Central Europe. The study also quantified waste production capabilities, it identified waste seasonality and analyzed disposal methods and related costs.

A method for skin storage was also identified so ensure a continuing supply of raw material for cutin extraction during the year. Microbiological analyzes were performed to control the stability of the preserved skins with positive results.

PLANT DESIGN, ASSEMBLY OF PROTOTYPE AND TESTING

A preliminary study and assessment of the pilot plant design solutions suitable for the cutin extraction process from tomato skins was carried out to evaluate the influence of the main parameters involved in the transfer of the various extraction phases from the laboratory to the prototype. The main parameters of extraction, time and temperature of the heat treatment, concentration of alkaline solution, optimum pH of cutin precipitation, several steps of purification were assessed by analyzing the yield and purity of the cutin extracted every time a change was introduced. Finally, the best conditions were selected, taking into account an ecological approach of the whole process.
A choice was made with regards to the type of centrifugal sorter, horizontal or vertical, to be used in the various stages of the extraction process. A key element was choosing the plant capacity. The assessment of the capacity and constant production output of the plant was carried out by means of specific laboratory tests for each stage. The plant was optimized based on environmental efficiency (electric energy and heat consumption) and financial sustainability of the process.
To minimize the environmental impact, resources and energy consumption were optimized through the recirculation of solutions and the reduction of processing temperatures and times. Moreover, both the solid and liquid waste generated by this process was used for biogas production. In this way there was no waste to be disposed of.

FORMULATION OF BIO-LACQUER AND APPLICATION. PACK TEST AND LIFE CYCLE ASSESSMENT (LCA) OF THE NEW ECO-CANS

To enable a standardisation of the extraction procedure, cutin was analyzed for its composition and monomeric units through different analytical techniques, FTIR, GPC, GC-MS. The dry residue was tested to be a fundamental parameter for a fast check and the optimal range was identified.

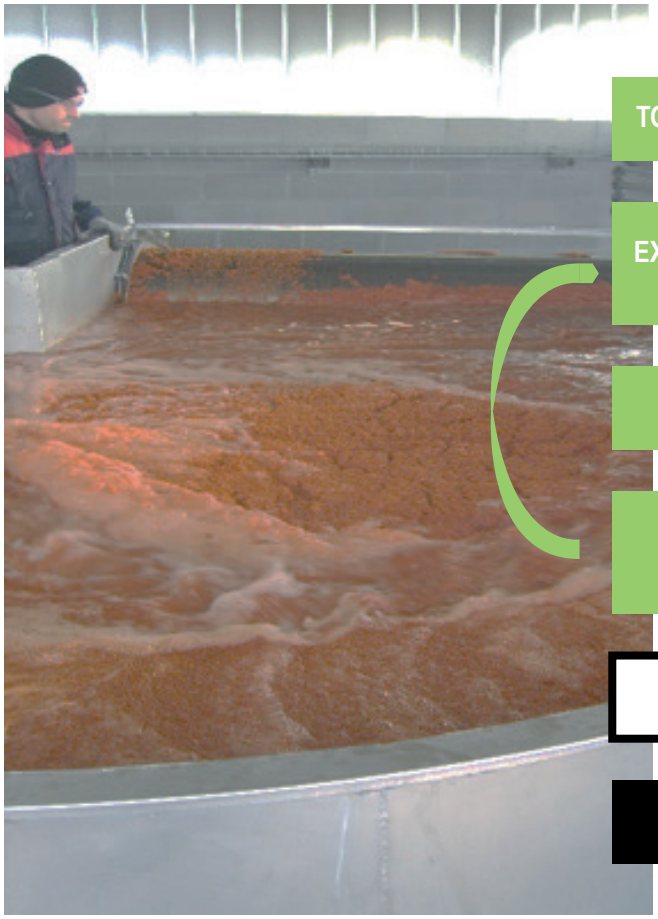
Based on the results obtained, different laboratory tests for the synthesis of bio-resin and for the formulation of the lacquer were carried out. A patent was obtained. The formulation with optimal properties was produced at an industrial level and applied to different materials with which cans were manufactured. After filling with different products cans were stored at different temperatures, in order to determine the behavior of the bio-lacquer during a pack-test of at least 12 months.
The study of the compliance of the new can with the National and European legislation on food contact materials was performed by means of global and specific migration tests in different simulants. To assess the environmental impact of the new cans in comparison with standard cans an LCA study was carried out.

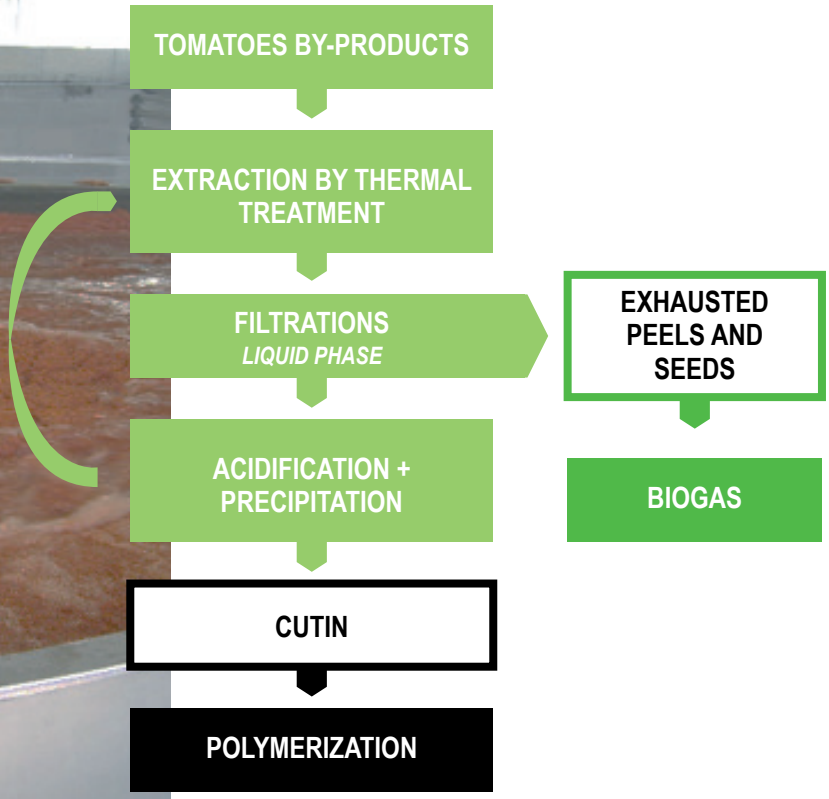
04 Results Obtained & New sustainable Packaging

The overall results of the demonstration project after about 3 years proved that processing tomato skins are a suitable raw material that can be an actual environment friendly alternative to obtain eco-cans with satisfactory performances for several types of food.
Positive results were obtained at every stage of the experimental work.

1. REALIZATION OF PILOT PLANT

The plant was built on the premises of the Virginio Chiesa Farm. The prototype was built in an area of the farm and was perfectly integrated with the other activities. The plant was commissioned on 27 October 2016 with a technical demonstration that recorded great success and interest. The plant has a capacity of 100kg/h of skins that are used to produce cutin with an averagely high extraction yield of 10-15%. The heat treatment is carried out at high temperature >120°C) for a short time (≤30').
The process developed is ecofriendly, since no organic solvents are used, but only aqueous solution at different pH values (acidic and basic).

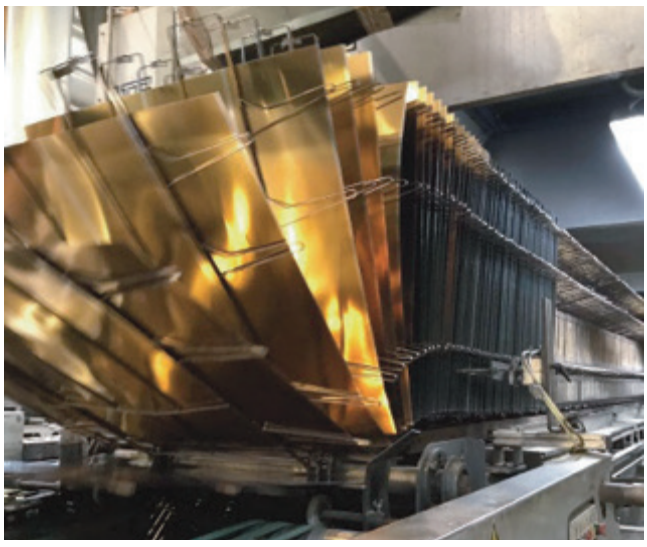




Solutions are recovered and reused several times; once the maximum number of recycles is reached, solutions are disposed of with biogas whereas solid waste is used to produce biogas, thus minimising its environmental impact. The prototype is not totally automated yet, but machines have been designed for future automation. Finally, the plant was built with a capacity/size equivalent to 10-20% of a future industrial line, and used all the technologies to be later employed in its industrialization, even though scaled-down. Furthermore, it is flexible enough to be applied to other vegetable waste.

2. SYNTHESIS OF BIO-RESIN AND INDUSTRIAL PRODUCTION OF BIOCOPACPLUS BIO-LACQUER

The GPC analysis verified that the extraction process results in a partial depolymerization of the natural bio-polymer; an average molecular weight of 650 g/mole was found. The GC-MS analysis showed that the degree of purity is very high; the extraction process set-up is very efficient, in fact the concentration of the 10.16 dihydroxydecanoic acid, the main component of tomato cutin, is 70-80%.



The optimum dry residue is in the 68-72% range.
Based on the results, the bio-resin was synthesized via homopolymerization.
An amount of about 5000 kg skins was processed to extract 250kg cutin, with fairly standardized features. Cutin was thus polymerized to obtain the bio-resin that is the main component (50-70%) of the new resin produced industrially. Cutin has no chemical or microbiological contamination, even though it comes from waste.

- **HEAVY METALS <10PPB**
- **SUGAR AND FIBERS <0,5%**
- **NO PESTICIDES RESIDUES**
- **NO MICROBIOLOGICAL CHARGE**

The lacquer produced (50kg) was applied on an industrial line without changing processing times and temperatures. It was applied on tinplate, tin free steel and aluminium.
The lacquer has good chemical and mechanical properties, good adherence and corrosion resistance. The results of all the tests it underwent were positive and comparable to those of standard lacquers. It is suitable for food contact according to Italian and European legislations. The overall and specific migration tests carried out on the cans in different simulants gave positive results in the legal range.

3. INDUSTRIAL PRODUCTION OF NEW ECO-CANS

About 3000 tin cans made up of 3 pieces and weighing 0.5kg each and their TFS ends were produced on the industrial line.
On the industrial line, 100 aluminium cans made up of 2 pieces were produced.

4. ENVIRONMENTAL IMPACT

By means of LCA the environmental impact of the new eco-cans protected with the bio-lacquer was compared with oil-based lacquer. The results are impressive: in comparison with a standard lacquer of fossil origin, emissions of CO_2 eq, are lower by 730 mg for each can.
A medium sized lacquer manufacturer produces on average 30,000 tons/year. If in an initial phase of project development at least 4,000 tons/year of standard lacquer can be replaced with lacquer derived from tomato, there will be a reduction of CO_2 eq emissions of 2 tons/year.
Considering instead that 650 K-tons of metal packaging are used in Italy every year, the reduction of emissions could be impressive, i.e. 1 million kg of CO_2 eq/year.

A further contribution to the total environmental impact reduction is due to better performances in the biogas production of the exhausted skins in comparison with non-treated ones.

SAMPLE	YIELD OF BIOGAS (dm^3 / Kg of V.S.)	VOLATILE SUBSTANCES (%)
TOMATO PEELS AS THEY ARE	43 dm^3 / Kg of V.S.	70 %
EXHAUSTED TOMATO PEELS	100 dm^3 / Kg of V.S.	65 %

05 Successful validation of new Bio-lacquer

Cans were filled with lentils and Borlotti beans, tomato sauce and pulp, diced meat. All cans were filled on the industrial line or reproducing an industrial filling with the pilot plant, thus verifying the lacquer resistance to the various filling processes. Cans were tested at different temperatures in order to determine the behaviour of the bio-lacquer during a pack-test of at least 12 months. Results were satisfactory and comparable to those of standard lacquers with all the products, thus highlighting the real and possible use of lacquer for metal food-contact packaging.

The new bio-lacquer obtained in BIOCOPACPLUS (from tomato waste source) is completely comparable to the lacquers available on the market, which are obtained from non-renewable sources, in terms of functional and hygienic properties (hardness, adherence, corrosion resistance, overall migration).

STARTING RAW MATERIALS	BIOLOGICAL AND CHEMICAL SAFETY OF THE TOMATO WASTE
SET-UP OF THE PROCESS PARAMETERS ON PILOT PLANT	TEMPERATURE AND DURATION OF THE HEAT TREATMENT CONCENTRATION OF THE CHEMICAL REAGENTS (INORGANIC ACID AND SODA) CONTROL OF PH DURING CUTIN PRECIPITATION PURIFICATION
BIO-LACQUER PRODUCTION	COMPLIANT WITH EU REGULATIONS ON FOOD CONTACT MATERIALS APPLIED TO STANDARD INDUSTRIAL LINES

06 Project Impact: Environmental & Socio-economic Benefits

The achievement of the BIOCOPACPLUS objectives has a positive impact on the whole agro-industrial supply chain, from farm to large retail, passing through lacquer manufacturers and packaging producers.

The use of a bio-lacquer replacing synthetic lacquers reduces the risk of environmental pollution in the steel recovery phase and thus promotes the recycling of metal containers, allowing the already high recovery percentages to increase even further.

The advantage for tomato growers and tomato processors is the value given to their processing waste and a consequent reduction in disposal costs. In Europe this industrial sector involves more than 3,000 processing firms. In Italy the disposal cost is around 4.00 Euro per ton (for transport). Every year the disposal cost of all Italian tomato waste amounts to more than 600,000 Euro.
The BIOCOPACPLUS project allows to save this cost and to enhance tomato by-products. The project has shown that tomato waste can be stored during the tomato campaign, and then used throughout the year for cutin extraction. This is an undeniable advantage for the continuous exploitation of the plants. Moreover, the project has also demonstrated that the waste remaining after cutin extraction can still be used for the production of biogas with better performances. So a double exploitation of tomato waste is possible. Thanks to the BIOCOPACPLUS lacquer, the tomato processing companies do not have costs, but benefits and gains.
Moreover, the European tomato industry is benefited also for the fact of using a more ecological packaging, i.e. metallic cans protected with cutin based lacquers.

- The new bio-lacquer is less influenced by geopolitical conditions than oil-based lacquer. Moreover, with the new procedure for bio-resin preparation, there will be fewer emissions into the atmosphere and the workplace will be safer, since the cutin extraction procedure does not use any organic solvents or dangerous substances. For the bio-lacquer synthesis no specific equipment or reagents other than those usually used for traditional lacquers are requested. This means that there will be no additional costs for bio-lacquer preparation and that all the equipment already used for traditional lacquers can be easily used for the new bio-lacquer.
In addition to this, the curing conditions of the bio-lacquer are completely compatible with the time and temperature used to cure the standard lacquers in industrial ovens. So no change to standard production lines and related processes is required. The financial relevance of this result is undeniable.

- Since the container produced is more easily recyclable, the metal packaging sector becomes more competitive. Furthermore, being a EU project, BiocopacPlus enjoys European visibility, which enables European SMEs to learn about the BiocopacPlus results and to consider the use of the bio-lacquer not only for metal food packaging, but also for non-food cans such as aerosols and other products.

- The production of a natural BPA-free lacquer is an advantage for the whole agro-food chain down to consumers because it solves the problems of migration of dangerous synthesized substances from the lacquer into food. The new BPA-free lacquer also allows exports of products to France, where in 2015 a very restrictive legislation banned BPA for food packaging.

- The pilot plant was realized using simple and well-known technologies without organic solvents, with high performances and yields at relatively low costs. Based on these considerations, the process can be easily replicated in other contexts or countries, including inside a tomato processing company to have a locally sourced lacquer (zero mileage).

Furthermore, it should not be forgotten that metal packaging, albeit easily recyclable, is currently perceived by consumers as having a high degree of non-freshness. The possibility of producing an innovative and green can is a great opportunity for the entire industry to re-launch this type of material, to make it more competitive than other materials and to gain a new market share for it. Since the production of tinplate and metal cans is growing steadily in other countries (from which Europe imports), especially in Asia (China, India, Malaysia and Korea) and South America, the innovative impact of the project is felt outside European countries as well.
response on specific topics.

The results of the social research confirmed this aspect along the entire supply chain.
For the social research a qualitative approach was adopted to anticipate reactions and to encourage an open response on specific topics.

Food companies were asked:

- **Do you think a project like BiocopacPlus may be interesting for your customers?**

They were also asked how much they agreed with the following statements:

- **Consumers are careful to the safety of food contact packaging**
- **Consumers may be available to pay more for a safe and sustainable packaging**
- **The enhancement of agri-food waste is a priority**

The companies that showed the greatest interest in the BiocopacPlus project are mostly foreign companies with more than 500 employees. The most important points that emerged were the attention of consumers for food safety (85% saying "partly and totally agree") and the enhancement of agri-food waste (88% saying "partly and totally agree").

The survey also highlighted other interesting aspects such as innovation (future company prospects, research & development), quality (meaning the maintenance of sensory properties, high level of preservation) and attention to cost competitiveness (approval of bio-lacquer, even if it costs much more than other lacquers).

Other questionnaires were prepared to be submitted to Bio supermarket and/or hypermarket chains. Eighty percent of the interviewed Retailer representatives stated that a sustainable packaging should not cost more; at the same time, the most significant points highlighted by the survey were: consumers' attention in terms of food safety, enhancement of agri-food waste and care for the environment.

With the aim of collecting information on consumers, representatives of consumers' associations and ethical purchasing groups were interviewed.
Fifty percent of the associations interviewed maintain that consumers would be ready to pay more to purchase a better quality product, whereas 75% of the representatives of the Ethical Purchasing Groups state that they would be available to pay more for a product packaged in a packaging coated with a safe, natural and ecofriendly lacquer. Consumers are interested in food safety, but ask to be better informed and made more aware on product use. For representatives of Ethical Purchasing Groups, BiocopacPlus's most interesting characteristic is the enhancement and reuse of agri-food waste, a topic linked to the fight against waste. Canned food is currently perceived as not very natural and for this reason it is not often purchased by Ethical Purchasing Group and consumers who usually buy organic products. BiocopacPlus may attract also these market segments to buy metal packages.

THE ADVANTAGES:

The **organic-based lacquer we are developing** meets the demand for sustainable production and protection of consumers' health since it:

- **Re-uses tomato processing by-products** for producing a greener lacquer for food packaging;
- **Reduces tomato waste** to be disposed of in compliance with the guidelines established in the EU waste directive 2008/98/EC;
- **Produces a natural lacquer** that protects consumers' health. The safety of food packaging and its related materials is a topic of great concern, very relevant and crucial for the entire agro-food supply chain;
- Provides a **safe and recyclable metal packaging**;
- Improves the **competitiveness** of the metal packaging sector.

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