# FINAL SCIENTIFIC REPORT
# (2022-2024)

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| **Competition** | Research Projects for Young Independent Teams |
| Contract no. | TE37/2022 |
| Project code: | PN-III-P1-1.1-TE-2021-0179 |
| Title: | Innovative technologies for valorizing lignocellulosic waste to bioplastics |
| Project acroniom: | LIGNOBIOPLAST |
| Project start date: | 15.05.2022 |
| Project end date: | 14.05.2024 |
| Duration: | 24 month |
| Total budget: | 450.000, 0 lei |
| Project website: | https://icia.ro/lignobioplast/ |
| Coordinating institution: | INCDO-INOE 2000, Filiala Institutul de Cercetari pentru Instrumentatie Analitica Cluj-Napoca |
| Proiect leader: | Dr. Lacrimioara Senila |

## 1. Objectives planned / achieved

### 1.1 Brief project description

One of the most pressing issues of our time is to find viable solutions to replace synthetic plastics with bioplastics, considering that the disposal of millions of tonnes of plastics into the environment creates significant and unmanageable problems.

The project proposed to develop new environmentally friendly technologies for the recovery of lignocellulosic wastes by using them for the production of bioplastics (PLA and PHA), to develop a pretreatment method with supercritical fluids in the presence of carbon dioxide for the separation of carbohydrates, their fermentation with microbial strains, the physico-chemical characterisation of the bioplastics obtained and the determination of their quality. A life cycle assessment (LCA) of the new technologies was also proposed to ensure their sustainability for large-scale implementation.

### 1.2 Objectives planned / achieved

| **Major objectives** | | |
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| **Nr. crt.** | **Objectives provided** | **Objectives achieved** |
| 1. | Development of innovative technologies for obtaining bioplastics (PLA and PHA) from lignocellulosic waste | **YES:** Two innovative technologies have been developed to produce bioplastics (PLA and PHA) from lignocellulosic waste. |
| 2. | Characterisation of bioplastics and determination of their physico-chemical quality | **YES:** The report on the physico-chemical characterisation of the two types of bioplastics (PLA and PHA) has been prepared. |
| **Specific objectives** | | |
| **Nr. crt.** | **Objectives provided** | **Objectives achieved** |
| 1. | Documentary study on the existing technologies for the production of bioplastics from lignocellulosic waste | **YES:** A documentary study on the selection of lignocellulosic wastes used for the production of bioplastics and a review of the existing technical |

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| | | documentation for the development of LIGNOBIOPLAST technology was carried out. |
| 2. | Lignocellulosic biomass pretreatment method | **YES:** Pretreatment Experiment Report: Pretreatment of lignocellulosic biomass with $CO_2$ under supercritical conditions |
| 3. | Development of technologies for the production of bioplastics using fermentation processes | **YES:** Two technologies (PLA and PHA) for obtaining bioplastics have been developed and designed taking into account the specific fermentation processes of each bioplastic |
| 4. | Report on the optimization of bioplastics production technologies (PLA and PHA) from lignocellulosic waste | **YES:** Optimization report on bioplastics (PLA and PHA) production technologies from lignocellulosic wastes was carried out. |
| 5. | Report on the physico-chemical characterization of the bioplastics obtained | **YES:** The physico-chemical characterization report of the two types of bioplastics (PLA and PHA) has been prepared. |
| 6. | Report with technical documentation of LIGNOBIOPLAST technology | **YES:** The technical documentation of the two technologies has been completed |
| 7. | LCA report | **YES:** LCA report of both technologies was carried out. |
| 8. | National patent request | **YES:** Patent application no. A00133/27.03.2024 was obtained |
| 9. | Dissemination by conference attending | **YES:** ►4 participations at international conferences; ►4 communications |
| 10. | Dissemination by publication of ISI articles | **YES:** ► 4 ISI articles (Q1/Q2, SRI>1) |

## 2. Presentation of the results obtained, of the result indicators achieved; of the non-achievements compared to the results estimated in the grant application (if applicable), with their justification

### Degree of achievement of estimated project results

| No. crt. | Estimated project results | Obtained results |
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| 1. | **Articles ISI published (SRI > 1): 3** | **4: 1►** Lacrimioara Senila, Ioan Botiz, Cecilia Roman, Dorina Simedru, Monica Dan, Irina Kasco, Marin Senila, Otto Todor-Boer, Processing of thin films based on cellulose nanocrystals and biodegradable polymers by space-confined solvent vapor annealing and morphological characteristics. *Materials*, **2024**, *17*, 1685. (Q1, SRI =1.659).; **2►** Lacrimioara Senila, Oana Cadar, Eniko Kovacs, Emese Gal, Monica Dan, Zamfira Stupar, Dorina Simedru, Marin Senila, Cecilia Roman, *L-Poly(Lactic Acid) Production by Microwave Irradiation of Lactic Acid Obtained from Lignocellulosic Wastes*, *International Journal of Molecular Sciences*, **2023**, 24, 9817. (Q2, SRI =2.264) **3►** Lacrimioara Senila, Emese Gal, Eniko Kovacs, Oana Cadar, Monica Dan, Marin Senila, Cecilia Roman, *Poly(3-hydroxybutyrate) production from lignocellulosic wastes using Bacillus megaterium ATCC 14581*, *Polymers*, **2023**, 15,4488, (Q1, SRI =1.787); **4►** Lacrimioara Senila, Daniela Alexandra Scurtu, Eniko Kovacs, Erika Andreea Levei, Oana Cadar, Anca Becze, Cerasel Varaticeanu, High-pressure supercritical $CO_2$ pretreatment of apple orchard waste for carbohydrates production using |

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| | | response surface methodology and method uncertainty evaluation. *Molecules*, **2022**, 27, 7783. (Q2, SRI =1.314). |
| 2. | **Communication and international conferences participations: 3** | **4: 1►** Eniko Kovacs, Oana Cadar, Daniela Alexandra Scurtu, Anca Becze, Dalma Kovacs, Lacrimioara Senila, Diana Elena Dumitras, *Production of bioplastics (L-polylactic acid and polyhydroxybutyrate acids) from agricultural biomass wastes*, 4th International Conference on Material Sciences and Engineering, 11-12 aug 2023, conferinta online (**Oral presentation**); **2►**Senila Lacrimioara, Kovacs Eniko, Scurtu Daniela Alexandra, Becze Anca, Kovacs Dalma, Cadar Oana, *Production of polyhydroxyalkanoates from lignocellulosic biomass*, 6th World Conference and Exhibition (WCCE-2023), 11-12 Sept, Barcelona, Spania (**poster presentation**). **3►**Kovacs Eniko, Senila Lacrimioara, Scurtu Daniela Alexandra, Becze Anca, Kovacs Dalma, Cadar Oana, *L-polylatic acid production from lignocellulosic biomass waste via microwave irradiation*, 6th World Conference and Exhibition (WCCE-2023), 11-12 Sept, Barcelona, Spania (**poster presentation**); **4►** Lacrimioara Senila, Eniko Kovacs, Daniela Alexandra Scurtu, Anca Becze, *Production of bioplastics from lignocellulosic biomass*, 21st International Conference Life Science for Sustainable Development, 15-17 sept 2022, Cluj-Napoca, Romania (**poster presentation**) |
| 3. | **Patent application: 1** | **1: 1►** Lacrimioara Senila, Oana Cadar, Eniko Maria Kovacs si Anca Becze, *Procedeu de obtinere bioplastic de acid polilactic din biomasa lignocelulozica prin iradiere in camp de microunde*, Cererea de brevet de inventie nr. A00133/26.03.2024. |
| 4. | **Study: 1** | **1**: **1►** Study on the existing methods to produce bioplastics from lignocellulosic waste |
| 5. | **Technologies: 2** | **2: 1►** Technology for obtaining polylactic acid (PLA) from lignocellulosic biomass; **2►** Technology for obtaining polyhydroxyalkanoate (PHA) from lignocellulosic biomass. |
| 6. | **Experimental data: 7**<br><br>**Experiment reports** | **7: 1►** Report on the pretreatment of lignocellulosic biomass, **2►** Report on the fermentation processes for the production of bioplastics (PLA and PHA) – initial; **3►** Report on the fermentation processes for the production of bioplastics (PLA and PHA) - final; **4►** Experimentation report on bioplastics production technologies (PLA and PHA); **5►** Experimentation report on the optimization of bioplastics production technologies (PLA and PHA); **5►** Physico-chemical characterization reports of the bioplastics obtained (PLA and PHA); **6►** Technical documentation report PLA and PHA technology and **7►** LCA Technologies Report. |
| 7. | **Project pag. web** | https://icia.ro/lignobioplast/ |

## 3. Estimated impact of the results obtained, underlining the most significant result obtained

| Nr. crt. | Result | Estimated impact |
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| 1. | Technology for obtaining polylactic acid (PLA) from lignocellulosic biomass | Further development and technology transfer to an SME with the capacity to produce and market a biodegradable product made from biodegradable waste, using a sustainable and environmentally friendly technology. |
| 2. | Technology for obtaining polyhydroxyalkanoate (PHA) from lignocellulosic biomass | Further development and technology transfer to an SME with the capacity to produce and market a biodegradable product made from biodegradable waste, using a sustainable and environmentally friendly technology. |
| 3. | LCA technologies report | Technological, economic and environmental impacts of PLA and PHA technologies. The environmental impact is lower compared to the production of conventional bioplastics. Economic impact: reduced raw material costs, energy efficiency, production of biodegradable products. |
| 4. | Patent application | Possibilities of commercialization |
| 5. | ISI articles | Recognition of the research activity of the project team |
| 6. | Communications | |

**The most significant result: Technology for obtaining polylactic acid (PLA) from lignocellulosic biomass**

**Presentation Technology for obtaining polylactic acid (PLA) from lignocellulosic biomass**

The technology developed in this project for the production of polylactic acid (PLA) from lignocellulosic biomass leads to a biodegradable bioplastic that can replace plastics produced by conventional methods. The technology for converting lignocellulosic waste into PLA includes the following conversion steps

1. Pretreatment of lignocellulosic biomass with $CO_2$ under supercritical conditions to break down the complex structure of the lignocellulosic biomass to separate hemicelluloses and release fermentable sugars;
2. Simultaneous saccharification and lactic acid fermentation process - the process of converting cellulosic components into simple sugars under the action of cellulase and simultaneously converting the sugars into lactic acid using genetically modified bacteria *L. rhamnosus* ATCC 7469 under controlled conditions such as temperature, pH, and nutrient levels.
3. Purification of the lactic acid by n-butanol extraction to remove impurities and by-products.
4. Polymerisation of lactic acid by microwave irradiation on PLA.

**Advantages of PLA production technology from lignocellulosic biomass**

- Polylactic acid is obtained from renewable sources;
- The pretreatment method used to extract the carbohydrates is an environmentally friendly method using only water and carbon dioxide under supercritical conditions;
- Combines two methods (hydrolysis and fermentation) in one process, which shortens the lactic acid production process (48 hours);

- Uses the microwave irradiation polymerisation method, which significantly reduces the PLA production time;
- The new PLA obtained can be used for the production of biodegradable packaging materials or can be blended with other polymers, plasticisers or additives and used as a biocomposite material.

Project leader,
Dr. Lacrimioara Senila