Elsa Vieira

REQUIMTE/LAQV, ISEP, Polytechnic of Porto

Jointly elaborated by: University of the Aegean

AGRIMA

Eco-friendly Bioplastics and Biocomposites – From Chestnut Waste to Green Materials: Part 1

Funded by the European Union

Erasmus+ Enriching lives, opening minds.

Higher education

erasmus+ PORTUGAL EDUCAÇÃO E FORMAÇÃO

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Agri-food Waste Management for Sustainable bio-economy through Higher Education curricula and upskilling

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PORTUGAL EDUCAÇÃO E FORMAÇÃO

Goals

AGRIMA aims to foster universities' **capacity building** for the **green transition** through **innovative practices and higher education curricula updating in agri-food waste management** for the **circular bioeconomy**.

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AGRIMA addresses:

1. **Advancing pedagogical methods** for industrial agri-food waste valorisation **based on business-academia synergies**.
2. **Integrating citizen science** in bio-economy-enhanced waste valorisation as a means of **civic engagement and environmental advocacy**.

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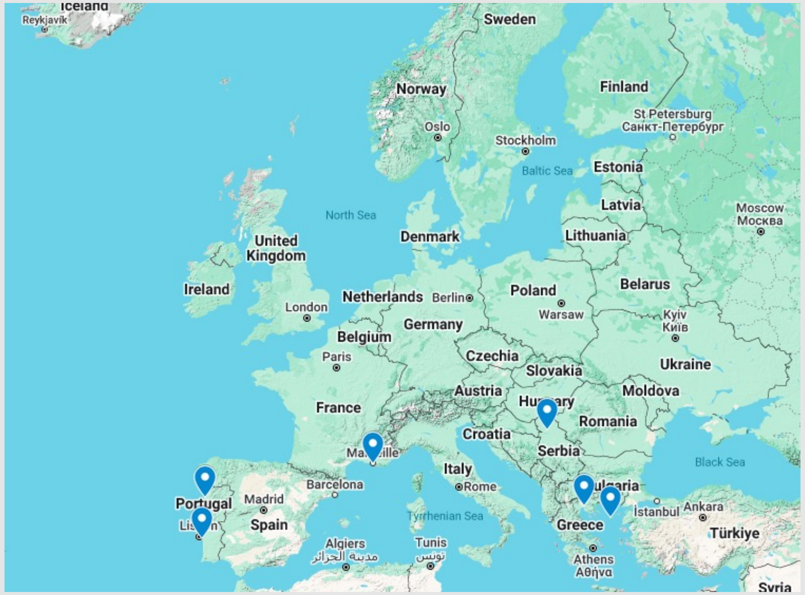
Partners



Aix*Marseille université
Socialement engagée

AVIPE
Associação de Viticultores do Concelho de Palmela

P.PORTO

UNIVERSITY OF THE AEGEAN

UNIVERSITAS STUDIORUM NEOPLANTENSIS
UNIVERSITY OF NOVI SAD

Web2Learn
Open, social learning

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ISEP STUDY RESEARCH DEPARTMENTS SERVICES

cidem
Centro de Investigação e Desenvolvimento em Engenharia Mecânica

cieti
centro de inovação em engenharia e tecnologia industrial

CISTER
Research Center in Real-Time & Embedded Computing Systems

gecad
Grupo de Investigação em Engenharia do Conhecimento e Apoio à Decisão

GAMES INTERACTION AND LEARNING TECHNOLOGIES

GRAQ
GRUPO DE REAÇÃO E ANÁLISES QUÍMICAS
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ISRC
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LSA
laboratório de sistemas autónomos
autonomous systems laboratory

SIIP PORTO

SOFTCPS
SOFTWARE TECHNOLOGIES FOR CYBER-PHYSICAL SYSTEMS

LAQV requimte | Laboratório Associado

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Sustainable Chemistry

A key player in engineering a Sustainable World

Elsa Marisa Ferreira Vieira

Back

Elsa F. Vieira has a licenciature in Nutrition and Food Science by the Faculty of Nutrition and Food Science (University of Porto, Portugal); a Master Degree in Quality Control- food and water by the Faculty of Pharmacy (University of Porto, Portugal) and a PhD in Sustainable Chemistry by the University of Porto and University of Lisbon (Portugal). Currently, she is a researcher at the department GRAQ (REQUIMTE associate laboratory) in the School of Engineering Polytechnic of Porto (ISEP, Portugal). Her research deals with the valorization of food by-products through the development of functional foods and analysis of bioactive compounds with anti-hypertensive, anti-diabetic, anti-inflammatory and anti-oxidant properties.

Research group
Environmental Chemistry

Position
Researcher

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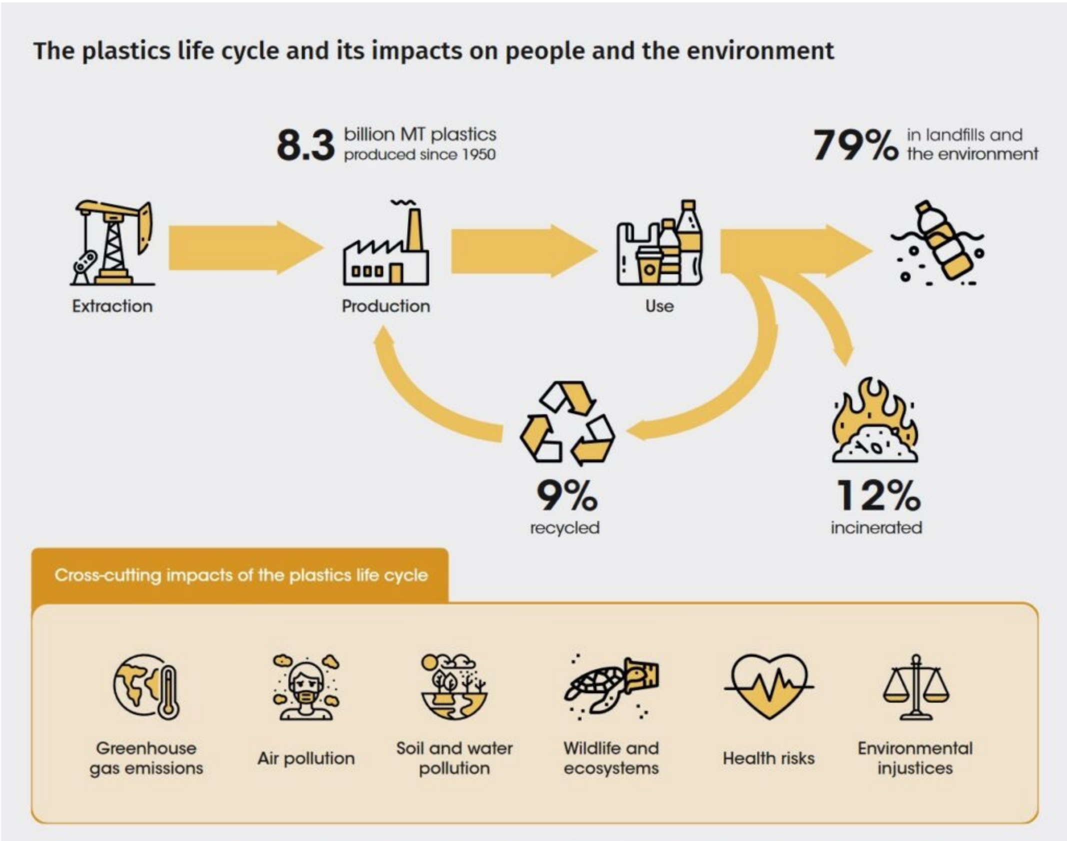
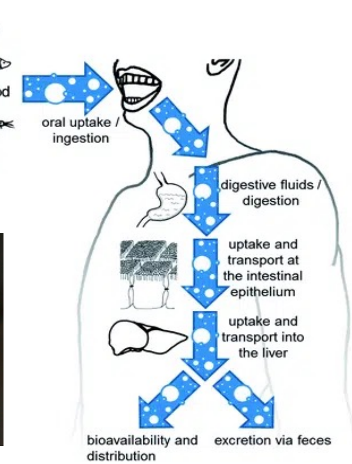
SCOPE

❑ PLASTICS LIFE CYCLE AND IMPACTS ON PEOPLE AND ENVIRONMENT



Source: Geyer, Jambeck & Lavender Law. *Production, use, and fate of all plastics ever made*. Sciences Advances. 2017.



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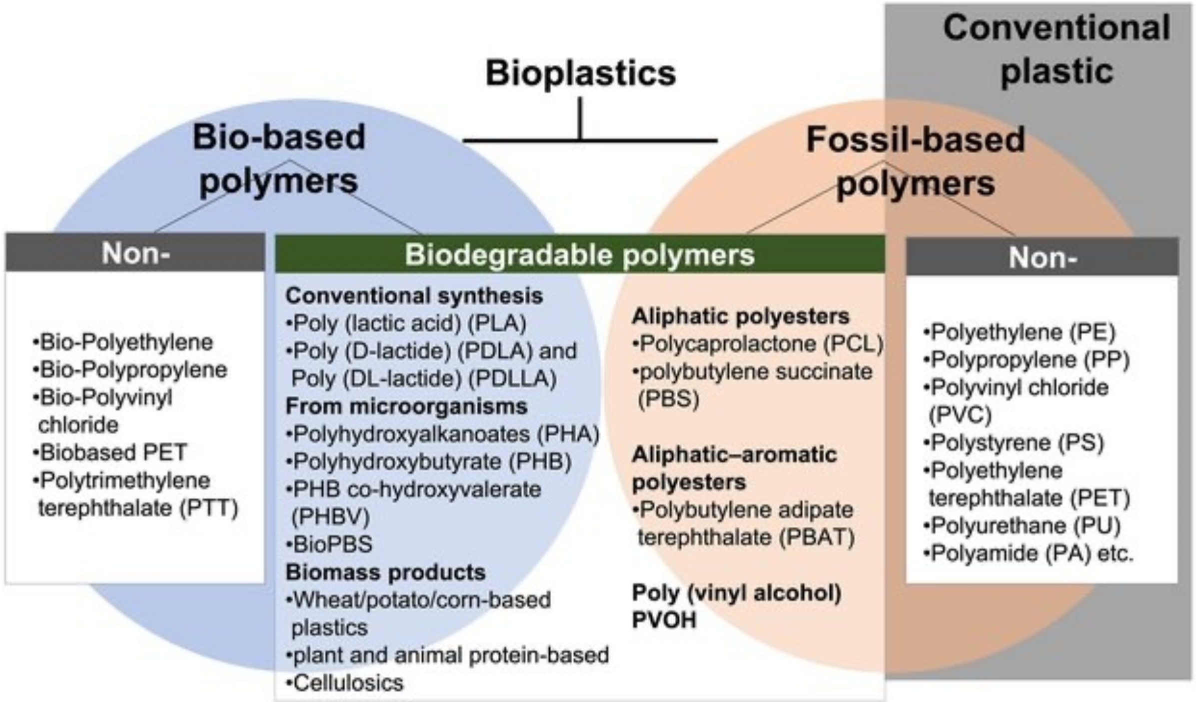
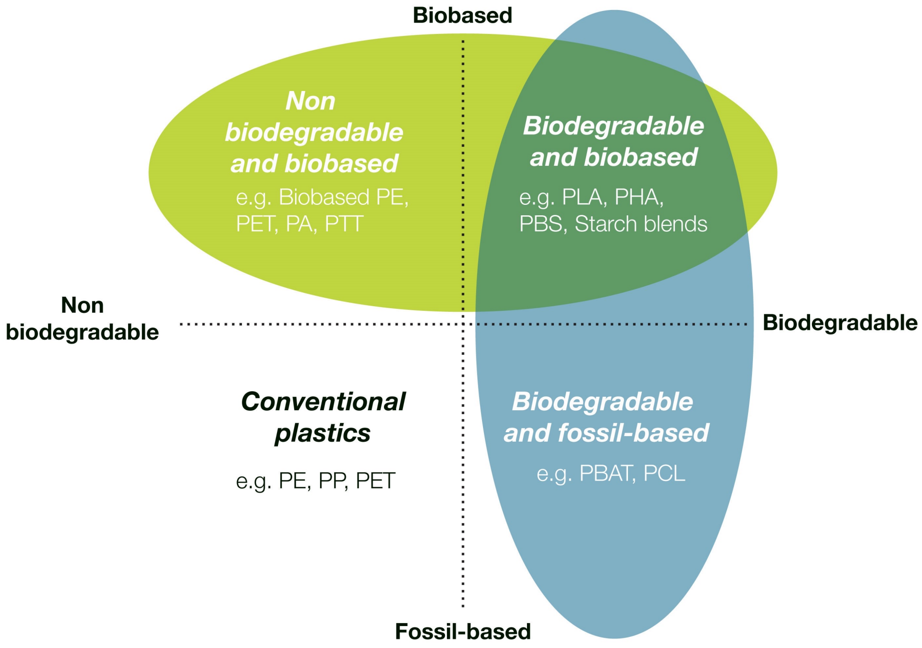
SCOPE

❑ BIOBASED PLASTICS



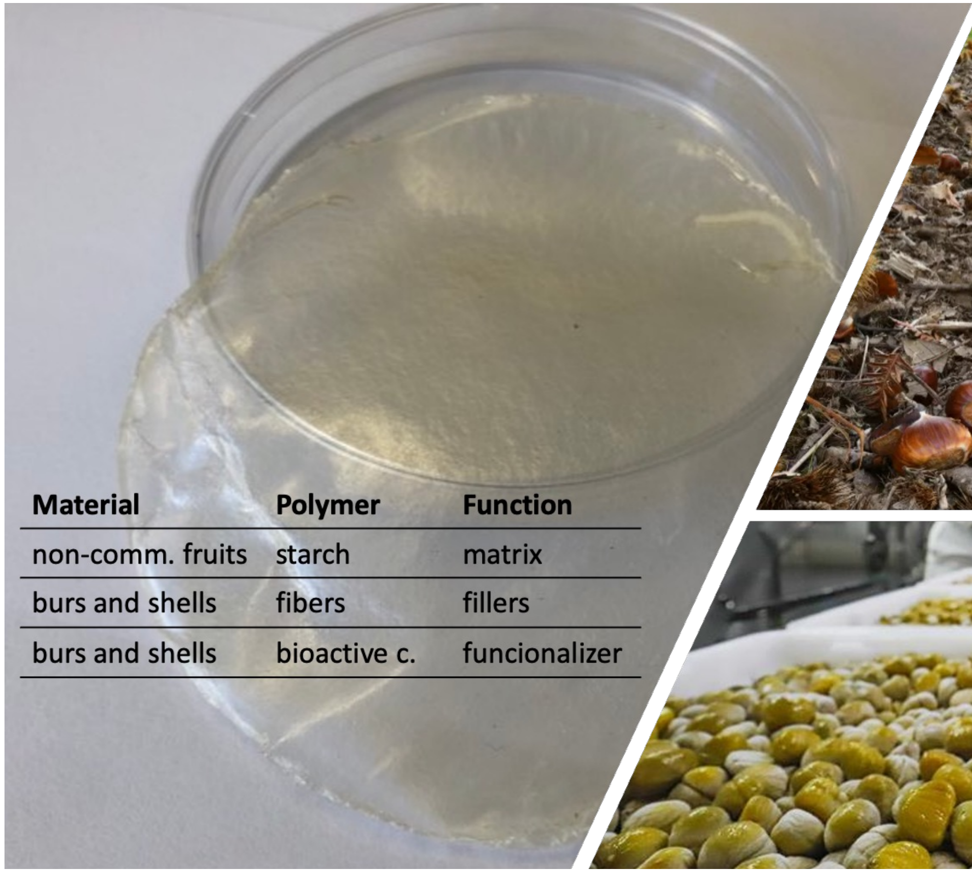


Source: https://doi.org/10.1007/s10924-020-01830-8

Source: https://www.plastics.org.nz/environment/bioplastics-degradables

INTRODUCTION

❑ BIOPLASTICS DESIGN

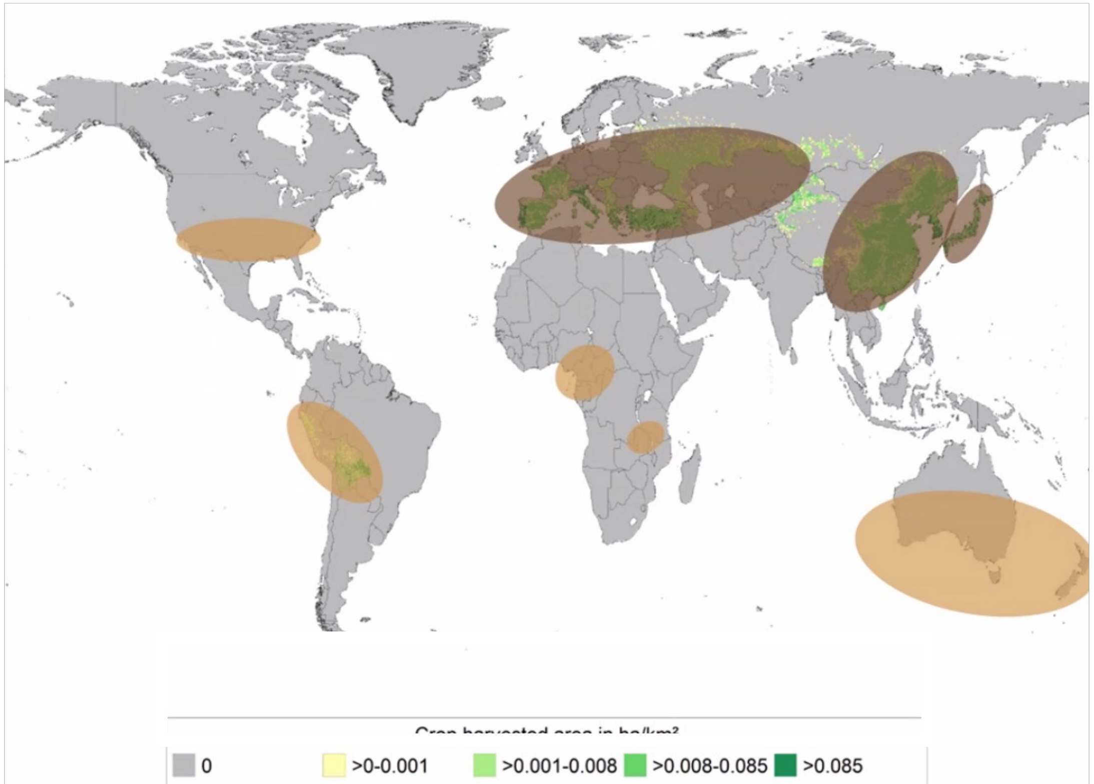


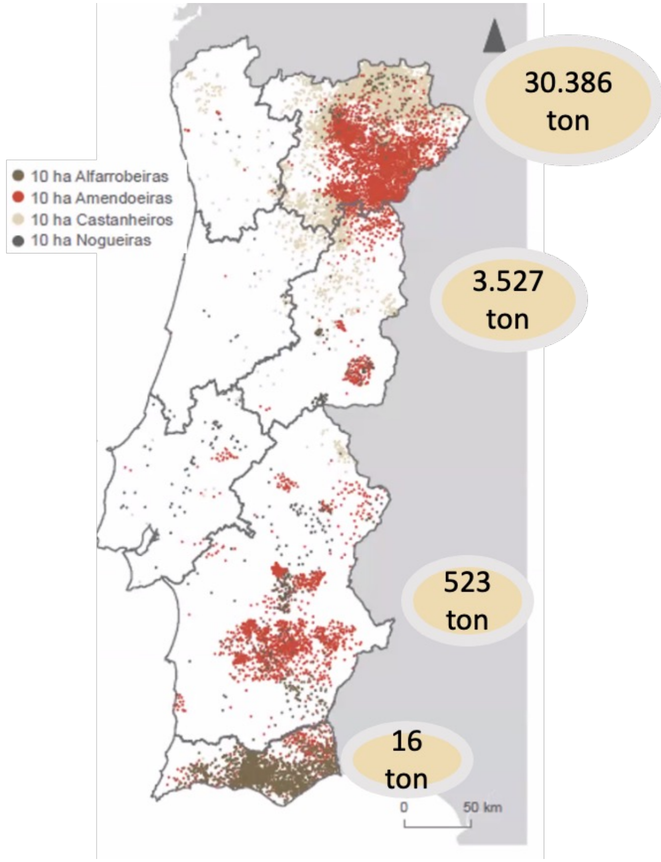
Material	Polymer	Function
non-comm. fruits	starch	matrix
burs and shells	fibers	fillers
burs and shells	bioactive c.	funcionalizer

INTRODUCTION

❑ CHESTNUT PROCESSING INDUSTRY

Source: REFCAST 2023, https://soscast.eu/site/





INTRODUCTION

❑ CHESTNUT PROCESSING INDUSTRY

111 760 t/year
(150 M€)

PRODUCTION
(44 704 t/year, 65 M€)

19%
Sold FRESH

74%
Sold FROZEN
(30 000 t/year)

6-7%
(solos)

By-products

6-7%

9-14% 6-10%
(energy)

30 000 t/year
(60 M€)

LOSSES 40-50%
(12 000 t/year, 24 M€)

* non-commercial value
[size <20 mm, defects (no kernel) and rottenness]

Burs: 67,500 ton
Flowers: 18,000 ton
Foliage: 69,000 ton

Source: REFCAST 2023, https://soscast.eu/site/

INTRODUCTION

❑ BIOPLASTICS DESIGN

Material	Polymer	Function
non-comm. fruits	starch	matrix
burs and shells	fibers	fillers
burs and shells	bioactive c.	funcionalizer

OBJECTIVES

- CHESTFILM PROJECT OVERVIEW

Prémios BPI ”la Caixa”
FCT CONCURSO DE PROJETOS
I&D MOBILIZADORES

Programa PROMOVE – Promove o Futuro do Interior Norte: municípios das NUTS III Alto Tâmega, Terras de Trás-os-Montes e Douro

“Desenvolvimento, promoção e valorização de novas culturas e produtos naturais para o mercado nacional e internacional (…)”

BPI | Fundação "la Caixa" FCT Fundação para a Ciência e a Tecnologia

OBJETIVOS DE DESENVOLVIMENTO SUSTENTÁVEL

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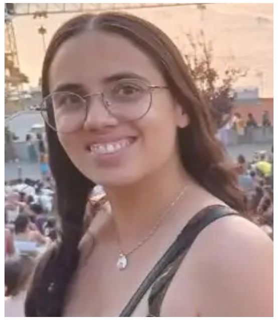
RESEARCH TEAM

						
PhD. Cristina Delerue-Matos	PhD. Valentina F. Domingues	PhD. Olga Freitas	PhD. Elsa F. Vieira	PhD. Elena Surra	PhD. Samara Rodrigues	MSc. Simão B. Silva

Email: emfva@isep.ipp.pt

https://www.isep.ipp.pt/Page/ViewPage/Chestfilm

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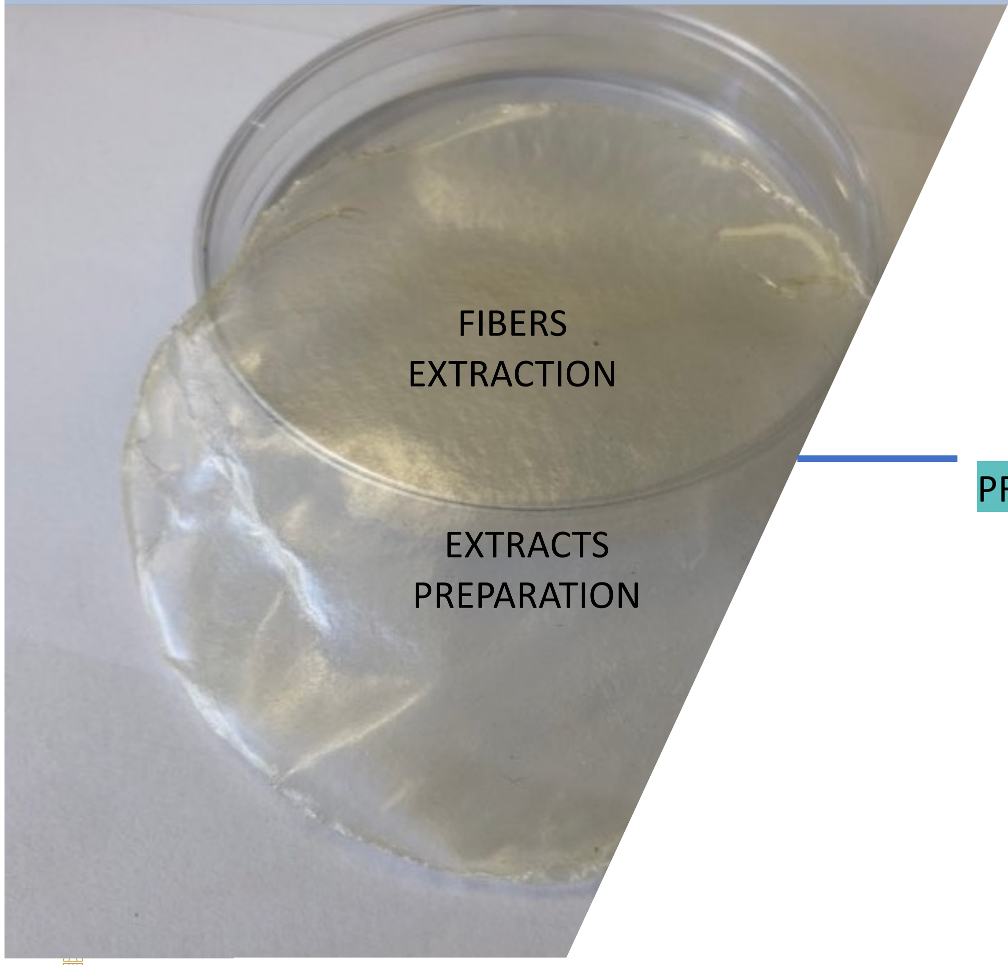
OBJECTIVES

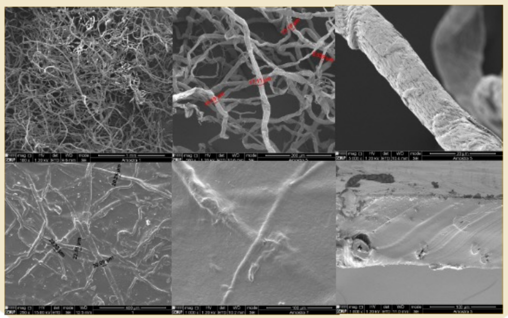


FILMS PREPARATION — FILMS CHARACTERIZATION — FILMS APPLICATION

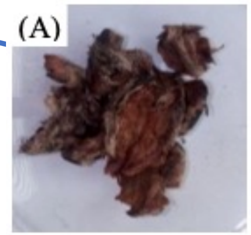
EXPERIMENTAL

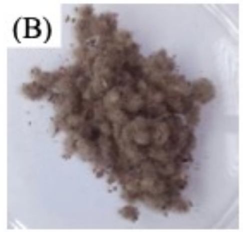
❑ FIBERS EXTRACTION

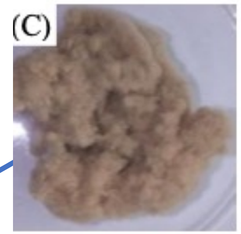
FIBER EXTRACTION



Chestnut shells
↓
Dehydration
↓
Mill
↓
Sieved
↓
Bleach
↓
Wash
↓
Dehydration


(A)


(B)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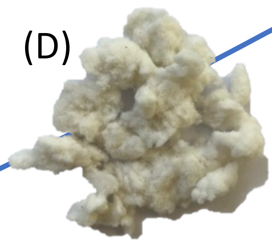
(D)

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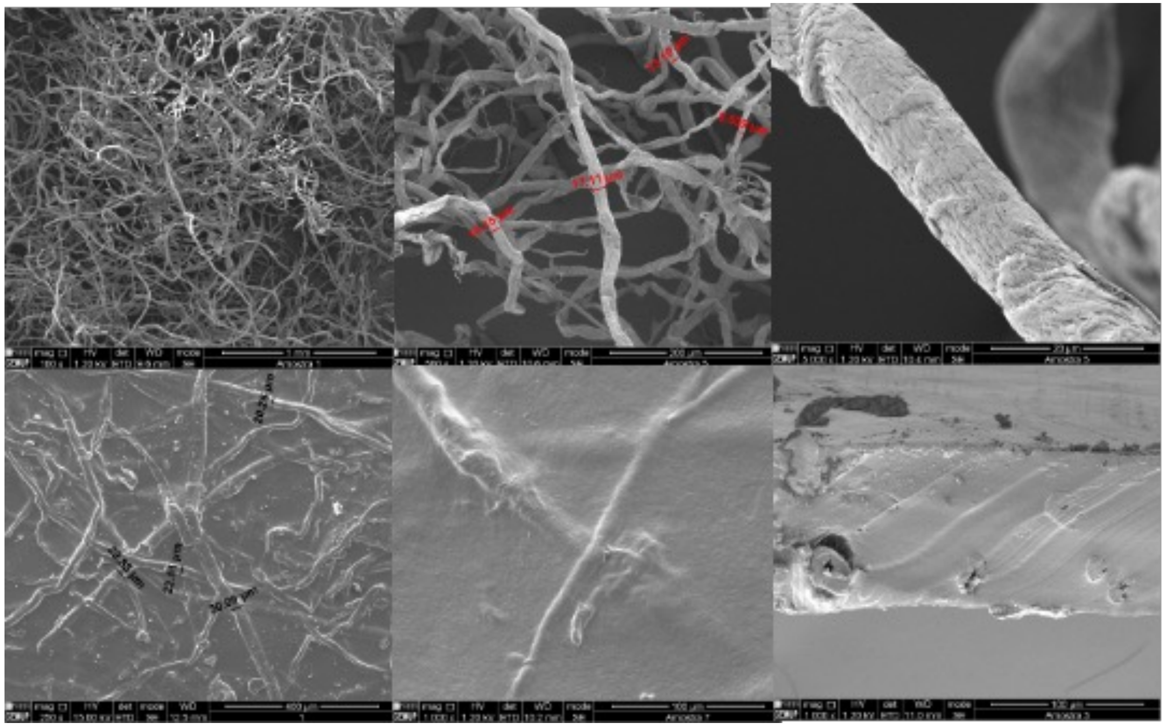
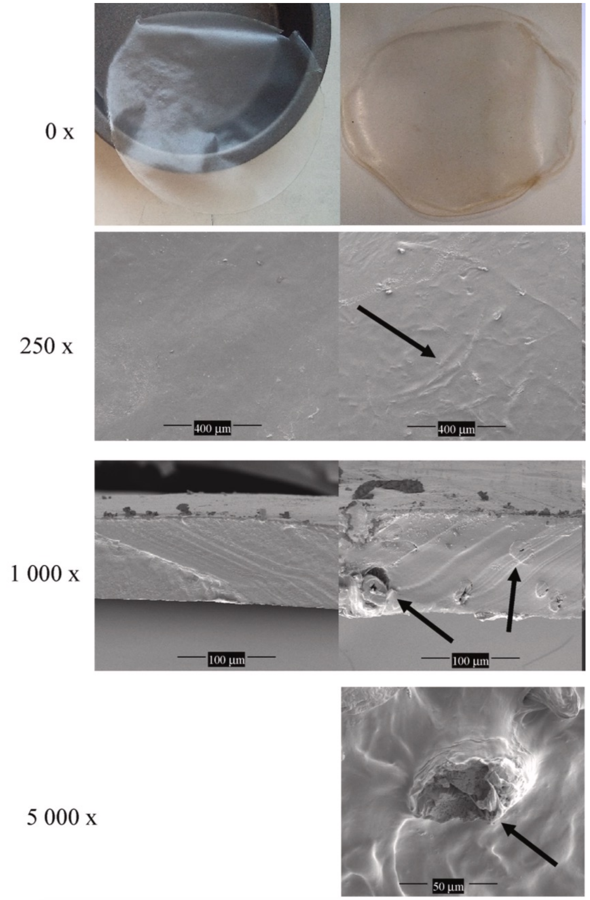
EXPERIMENTAL

❑ FIBERS EXTRACTION

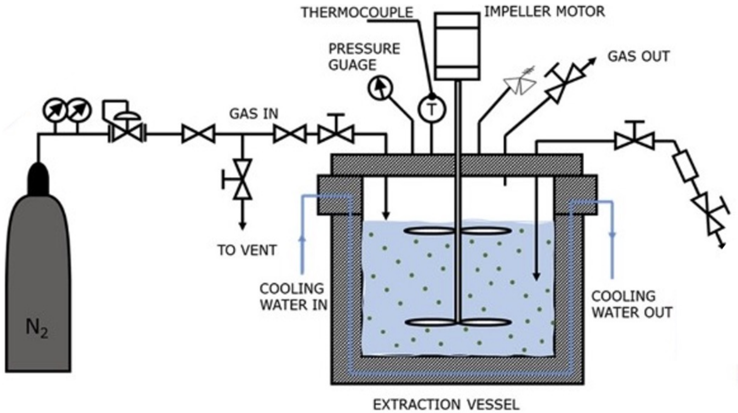




https://doi.org/10.1016/j.foodchem.2022.133609

EXPERIMENTAL

❑ PREPARATION OF BIOACTIVE EXTRACTS



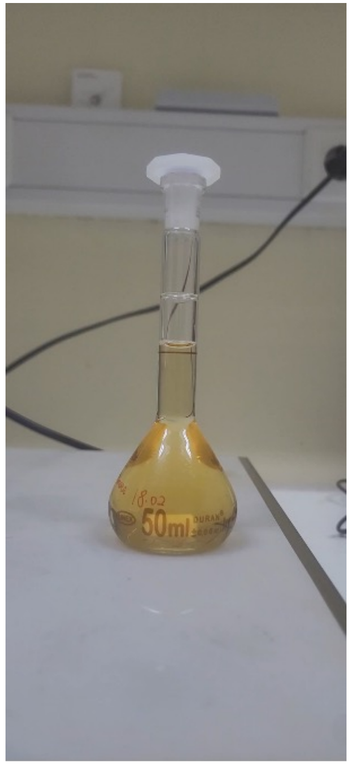
TPC: 450 ± 5.67 mg AAE/g DW
FRAP: 27.60 ± 1.84 mg AAE/g DW
ABTS$^{\cdot+}$: 52.05 ± 0.61 mg AAE/g DW
DPPH$^{\cdot}$: 5.83 ± 0.13 mg TE/g DW

SUBCRITICAL WATER EXTRATION
solid/solvent ratio of 1:10 (w/v),
220 °C, 30 min, 14.6 bar

https://doi.org/10.1016/j.foodchem.2020.127521

EXPERIMENTAL

❑ PREPARATION OF BIOACTIVE EXTRACTS



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EXPERIMENTAL

❑ FILMS PREPARATION BY "SOLVENT CASTING"

2, 4, 8, 16, 20 mg/100 mL
filmogenic solution

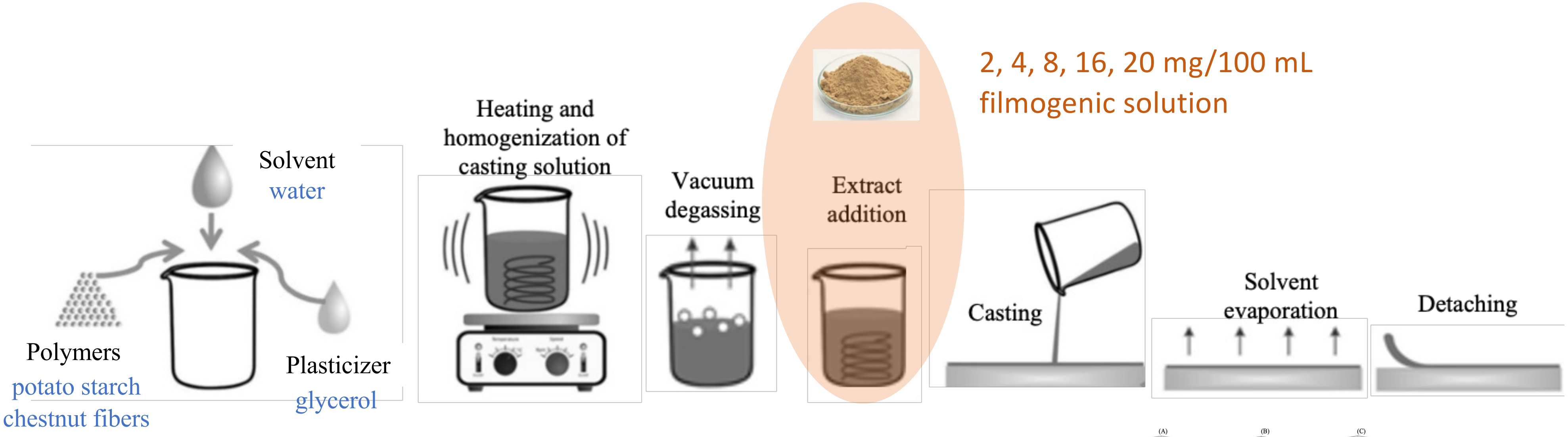


Table 3.3- Performance of RSM model in predicting the optimum composition to enhance the Elongation (Y1), Tensile Strength (Y2) and Elastic Modulus (Y3) of starch-based film.

Response	Optimum conditions			Predicted value (desirability)
	Glycerol (%)	CF (%)	CL (%)	
Y1, Elongation (%)				34.19 %
Y2, Tensile Strength (N)	50	10	0	7.31 N
Y3, Elastic Modulus (N)				4.15 N (66.9%)

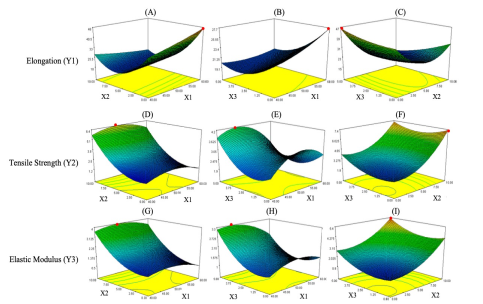
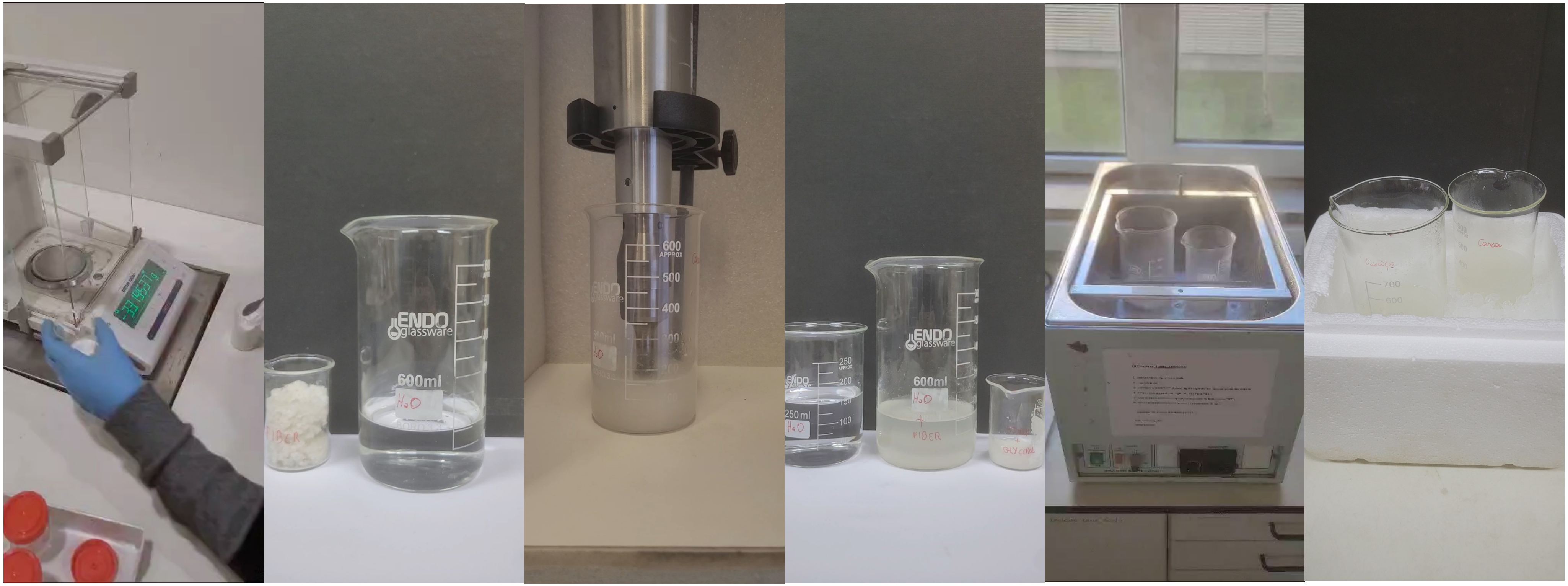


Figure 3.3- Response surface 3D plots for Box-Behnken design correlating independent variables to the three responses: elongation ((A), (B) and (C)), tensile strength ((D), (E) and (F)) and elastic modulus ((G), (H) and (I)). Independent variables: X1-Glycerol (% (w/w)), X2-CF (% (w/w)) and X3- CL (% (w/w)).

https://doi.org/10.1016/j.foodchem.2022.133609

EXPERIMENTAL

❑ FILMS PREPARATION BY ”SOLVENT CASTING”



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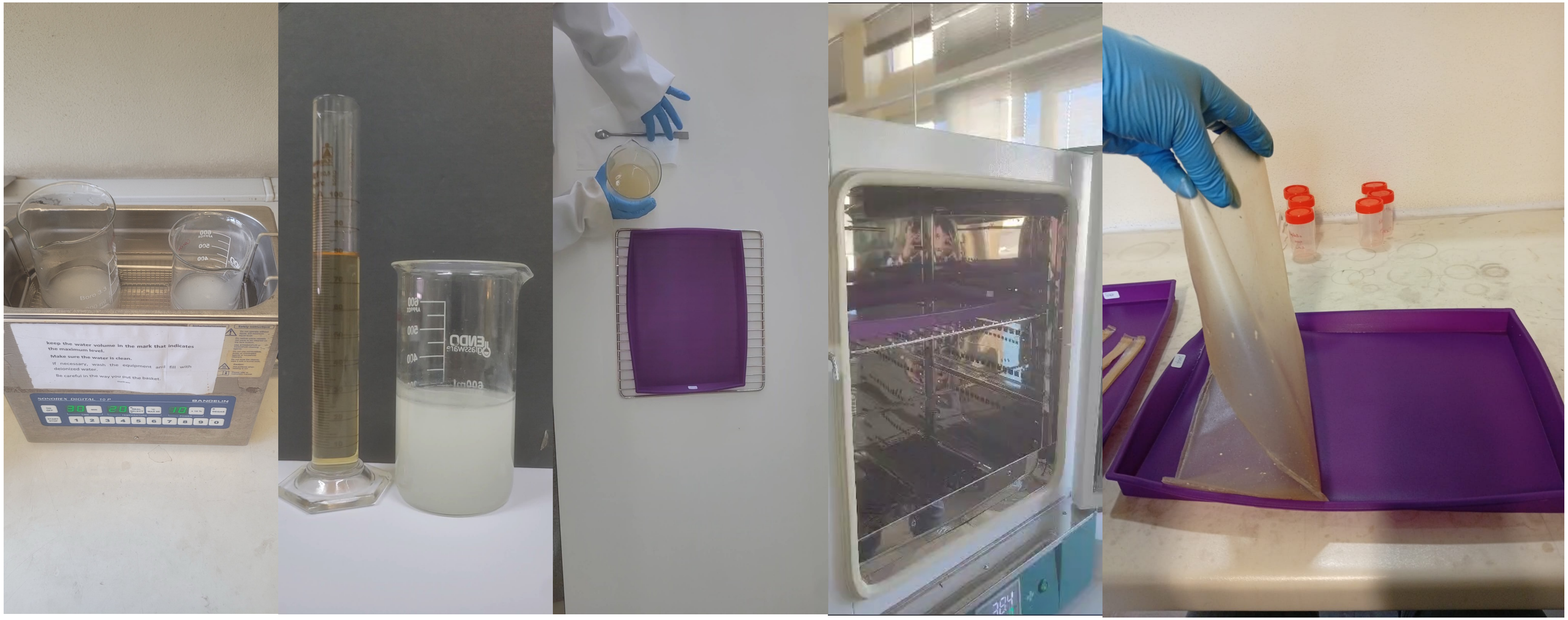
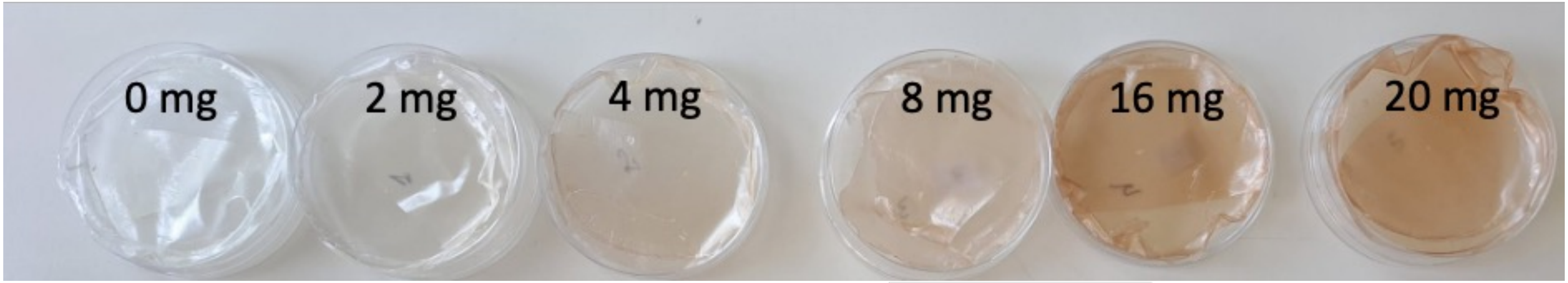
❑ FILMS PREPARATION BY "SOLVENT CASTING"



EXPERIMENTAL

❑ FILMS CHARACTERIZATION



Barrier properties

UV-barrier capacity
Water vapor permeability

Optical properties

Color
UV-barrier capacity
Transparency
Opacity

Mechanical properties

Elongation at break
Tensile strenght
Elastic modulus

Other properties

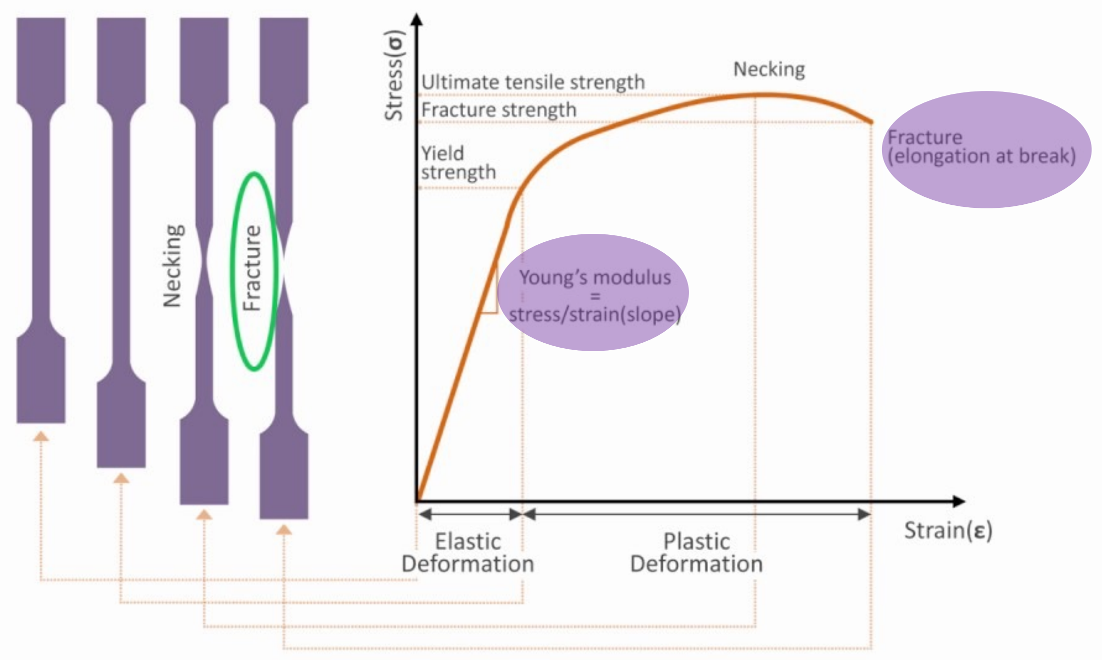
Thickness
Water content
Water solubility
Morphological structure

Antioxidant properties

Total phenolic content
$ABTS^{\bullet+}$ and $DPPH^{\bullet+}$ scavenging activity

EXPERIMENTAL

❑ FILMS CHARACTERIZATION >> MECHANICAL PROPERTIES



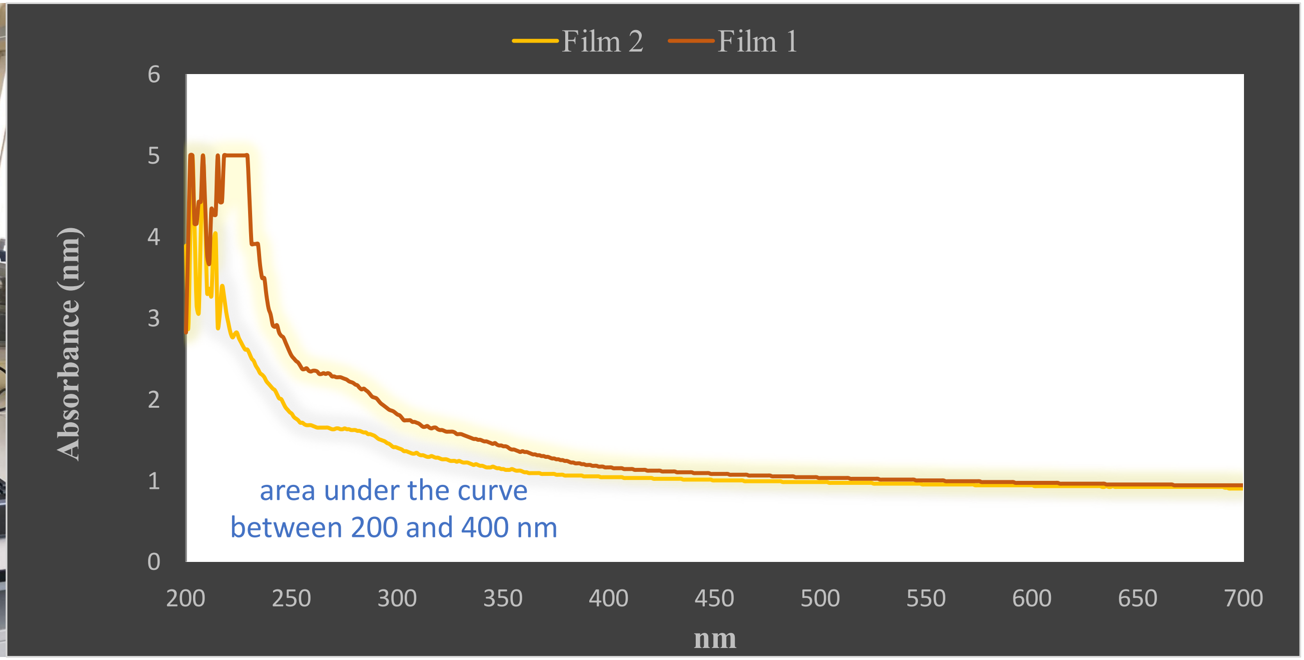
Tensile strength (N/mm²): measures the maximum stress a film can sustain under tension

Young's modulus (N/mm²): measures the ratio between the stress and the corresponding strain

Elongation at break (%): Measures the maximum deformation before rupture

EXPERIMENTAL

❑ FILMS CHARACTERIZATION >> OPTICAL PROPERTIES



UV barrier (UA × nm): Measures the film's capacity of absorbing UV light

Opacity (Abs_{600}/mm): Measures the quantity of light retained by the film

$$\text{Opacity}\left(\frac{\text{AU}}{\text{nm}}\right) = \frac{\text{Abs 600 nm}}{\text{thickness (mm)}}$$

$$\text{Transparency}\left(\frac{\text{AU}}{\text{nm}}\right) = \frac{-\log\ (\text{Abs 600 nm})}{\text{thickness (mm)}}$$

EXPERIMENTAL

❑ FILMS CHARACTERIZATION >> DESINTEGRATION

European standard
French standard

NF EN 13432
November 2000

Classification index: **H 60-140**

ICS: 13.030.50; 55.020

Packaging

Requirements for packaging recoverable through composting and biodegradation

Test scheme and evaluation criteria for the final acceptance of packaging

F : Emballage — Exigences relatives aux emballages valorisables par compostage et biodégradation — Programme d'essai et critères d'évaluation de l'acceptation finale des emballages
D : Verpackung — Anforderungen an die Verwertung von Verpackungen durch Kompostierung und biologischen Abbau — Prüfschema und Bewertungskriterien für die Einstufung von Verpackungen

Test Criteria	Overview	Test Method(s)	Test Requirements
Biodegradability	Test is a measure of the extent to which the product is converted to water, carbon dioxide and/or biomass by means of microbial action. Requires that every product component, material or item be biodegradable.	Biodegradability shall be demonstrated through laboratory testing and carried out to the correct methodology i.e. ISO: **14855** - biodegradability under controlled aerobic composting conditions **14851** – aerobic degradability in water (oxygen demand) **14852** – aerobic degradability in water (evolved carbon dioxide)	Test is carried for a maximum of 6 months (dependant on how susceptible the product is to composting conditions) by which time the amount of carbon dioxide release must be at least 90% as much carbon dioxide given off by a reference/control sample.
Disintegration	Test designed to quantify the 'physical falling apart into small fragments of packaging and packaging materials'[3].	Test is carried out on the end product specification or as close to an end specification as feasible. The use of a pilot-scale test is utilised to recreate an industrial composting system. A sample of the test material is added to an organic waste fraction and is then sustained under relevant pilot-scale testing condition at 58°C for 12 weeks.	The standard requires that at the end of the period at least 90% of material must pass through a 2mm sieve.
Ecotoxicity	The residue from disintegration testing is utilised for ecotoxicity analysis the aim of which is to highlight any potential negative affects on the compost material.	Comparison of samples, one with and one without product material, which have gone through the disintegration tests are used to determine any negative toxicological affects e.g. pH, volatile solids, salinity, magnesium, N,P,K and ammonium nitrogen. The use of two higher plants tests which conform to the requirements of the OCED 208 "Terrestrial Plants, Growth Test".	The number of grown plants and the plant biomass within the sample and control sample are compared. Percentage is provided against the blank compost. The percent should be no less than 90% of the blank sample.
Chemical Analysis	Heavy metal concentrations are used to indicate any potential negative affects of the end compost quality. Especially important to composters going down a quality route i.e. PAS 100 / compost quality protocol.	Disclosure of all chemical element concentrations must be given to the certifying body as a way of disclosing the presence of hazardous substances. Analysis of heavy metals is normally undertaken by manufacturer of each constituent.	The 11 chemicals must be under the stated threshold concentrations shown in the EN 13432 standard.

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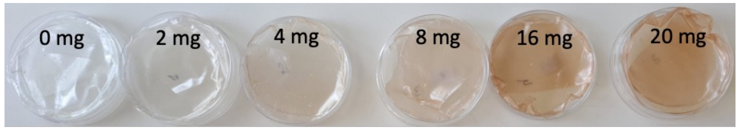
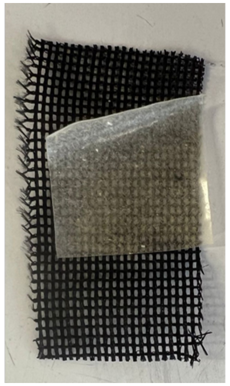
❑ FILMS CHARACTERIZATION >> DESINTEGRATION



Parameter	Conditions
Specific soil	Organic soil
Watering	Once a week
Time of storage	5 weeks
Control	PET plastic



Disintegration: the physical decomposition of film into tiny pieces.

Calculation: % disintegration based on mass differences.

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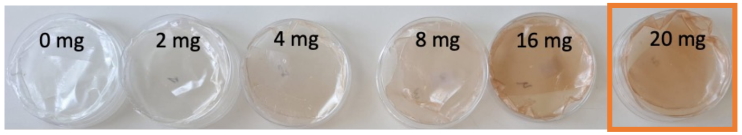
❑ FILMS APPLICATION



Cookies (7% moisture content)
Contact for 30 days

Conditions

25L 25 °C, light exposure

25sL 25 °C, protected from light

30L 30 °C, light exposure

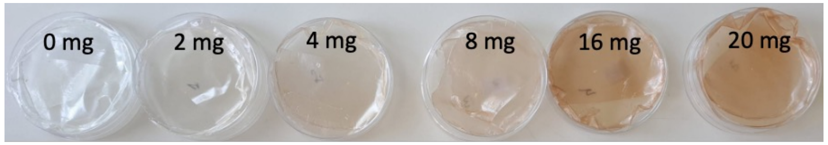
FILMS PERFORMANCE:

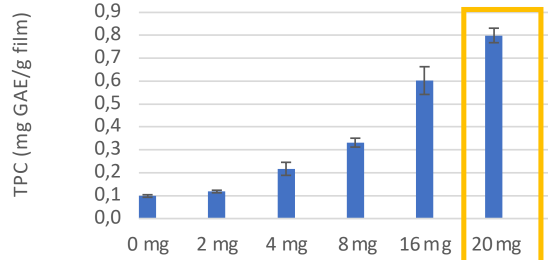
- MECHANICAL PROPERTIES
- WATER CONTENT
- WATER SOLUBILITY
- MIGRATION STUDIES

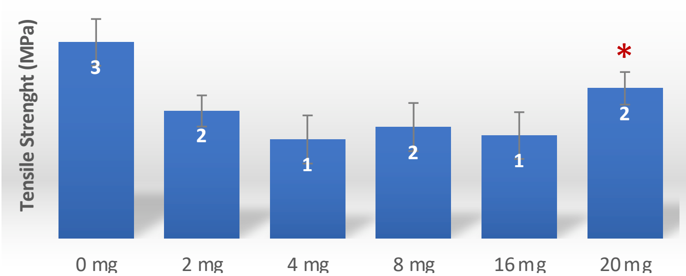
(Total Phenolic Content, ABTS$^{•+}$ and DPPH$^{•+}$ RSA)

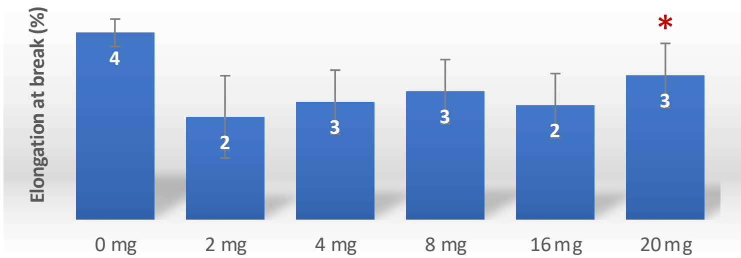
RESULTS

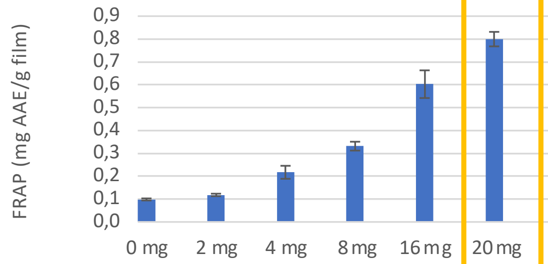
❑ FILMS CHARACTERIZATION

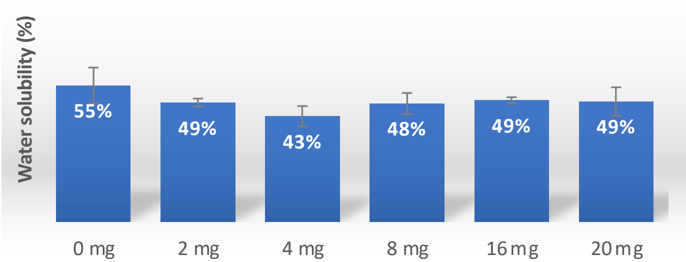


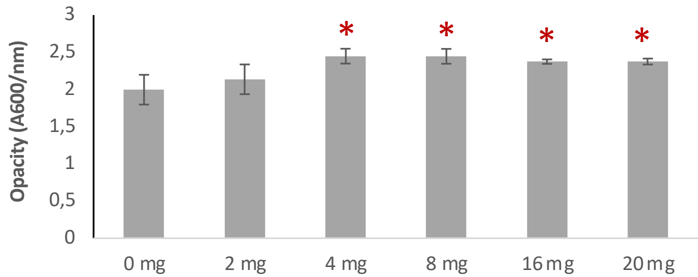


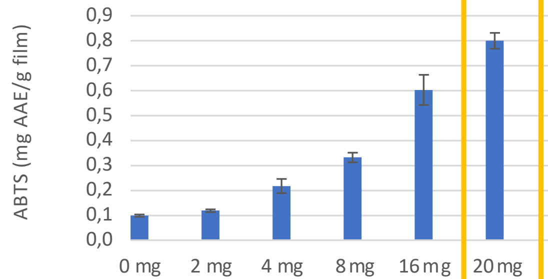












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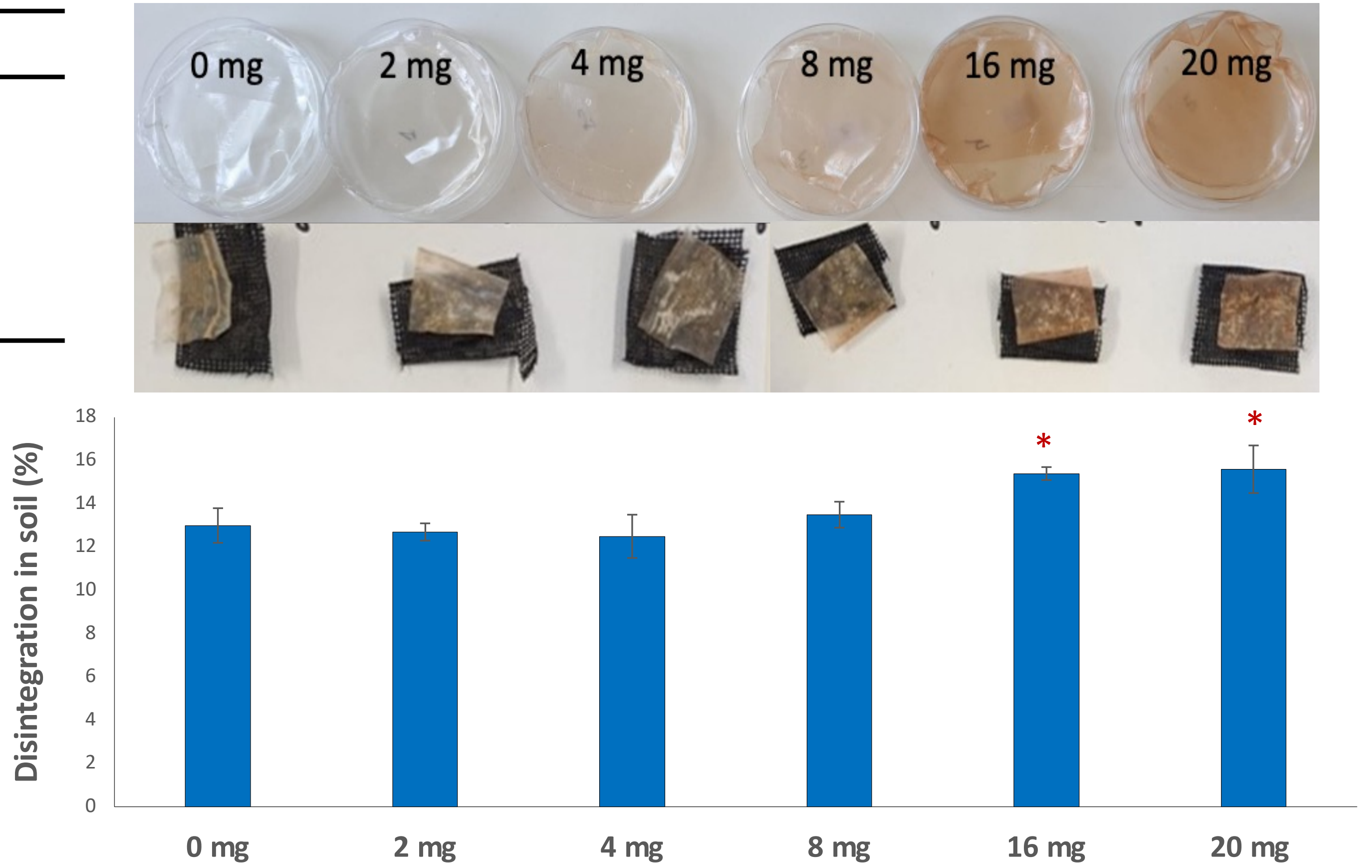
RESULTS

❑ FILMS CHARACTERIZATION

Parameter	Conditions
Specific soil	Organic soil
Watering	Once a week
Time of storage	5 weeks
Control	PET plastic



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RESULTS

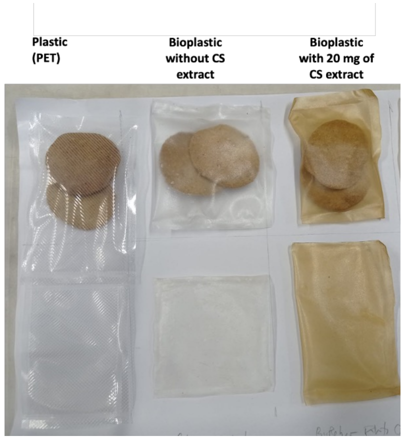
❑ FILMS APPLICATION

Plastic (PET) | **Bioplastic without CS extract** | **Bioplastic with 20 mg of CS extract**

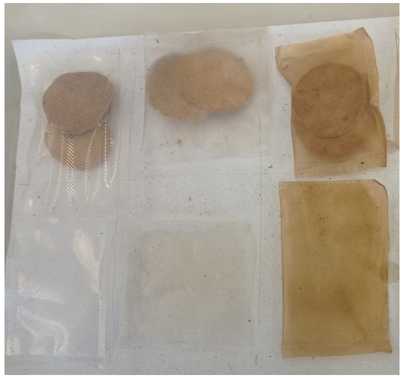
RESULTS

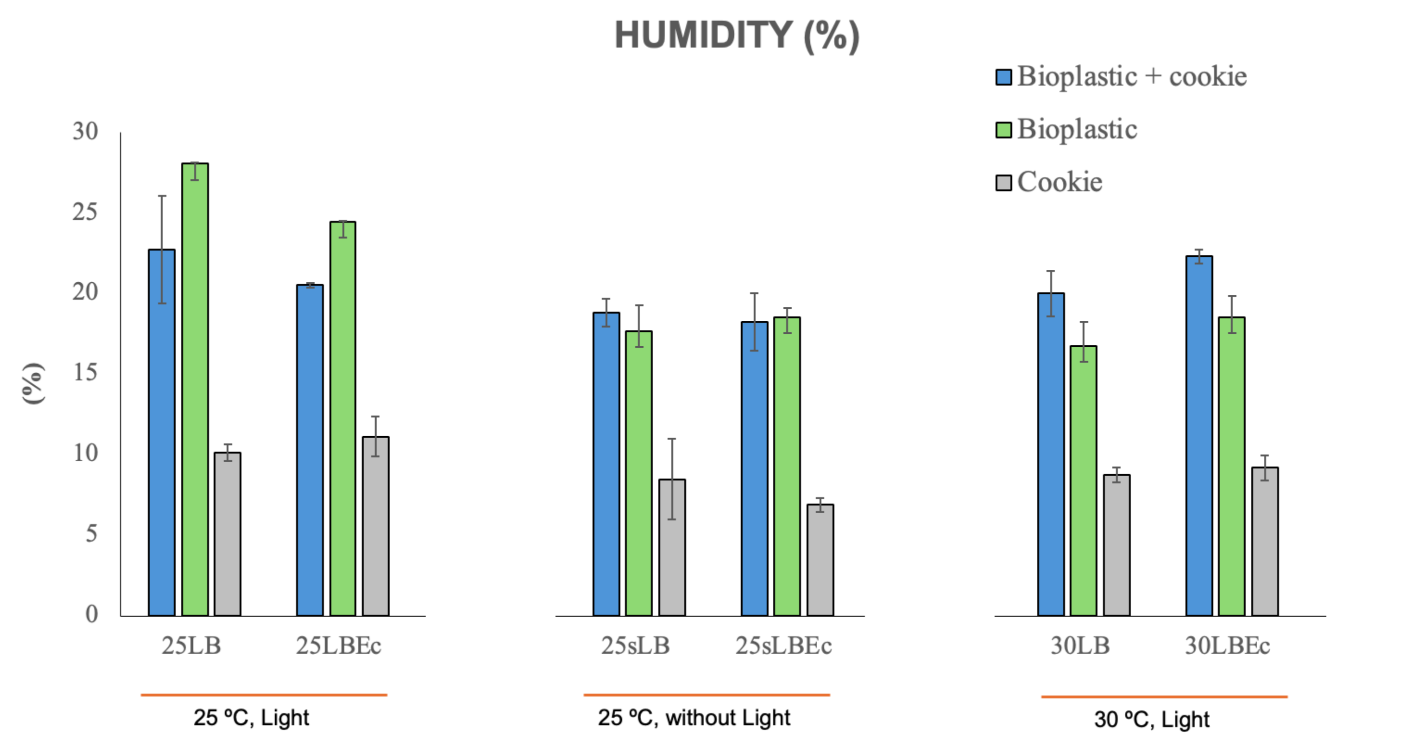
❑ FILMS APPLICATION

DAY 0



DAY 30





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RESULTS

❑ FILMS APPLICATION

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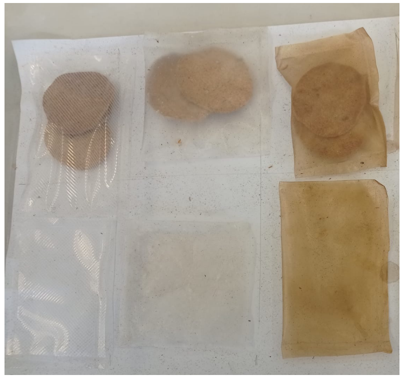
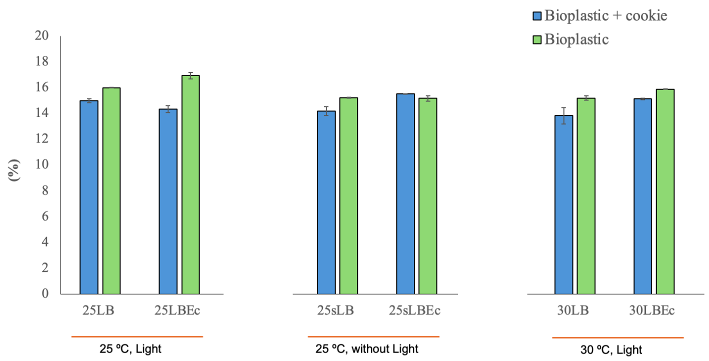
DAY 0

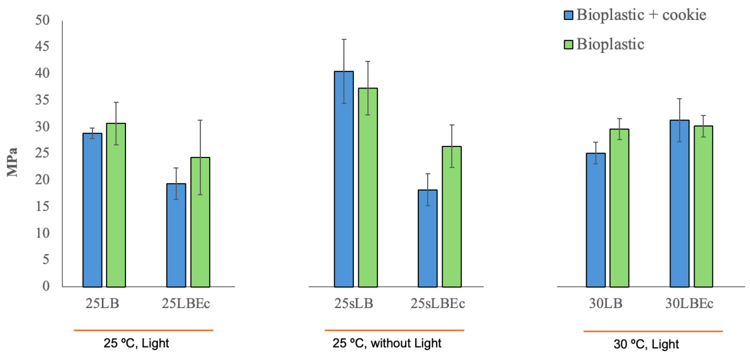
DAY 30



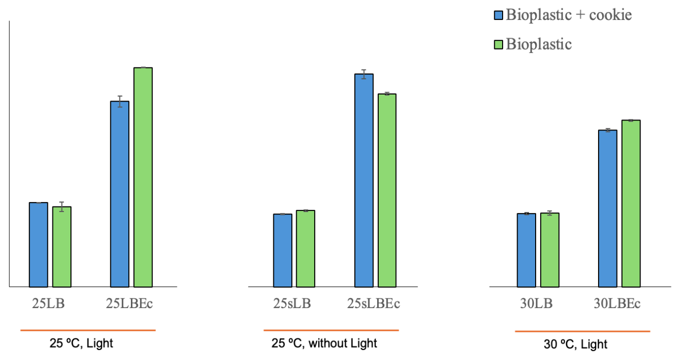
WATER SOLUBILITY (%)



YOUNG`S MODULUS (MPa)



UV BARRIER CAPACITY (AU x nm)



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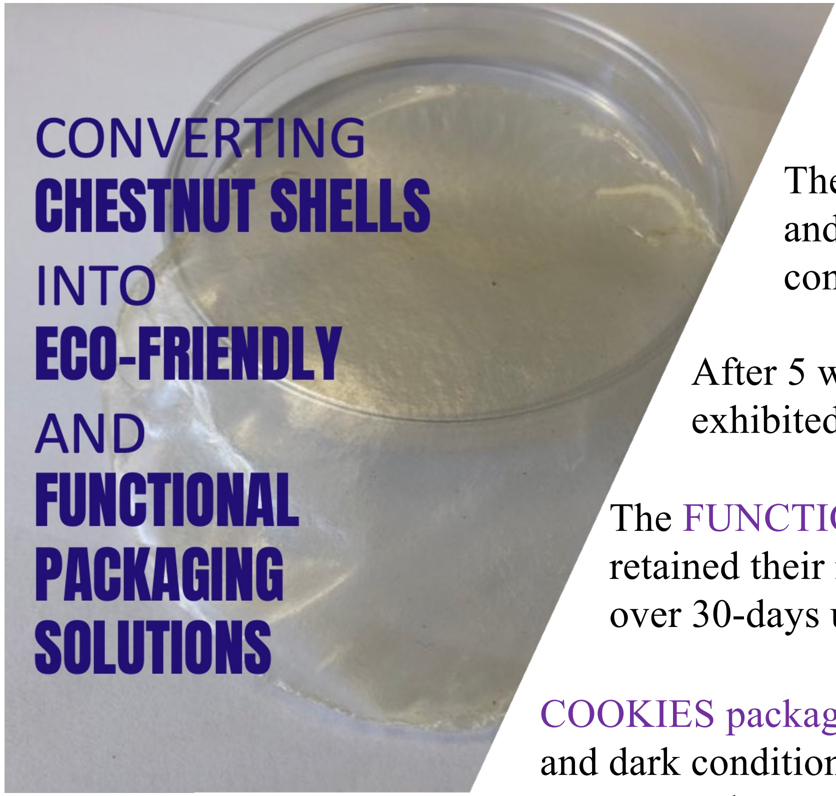
CONCLUSIONS



The chestnut shell **SWE extract** was successfully incorporated within reinforced starch-based film

The FUNCTIONALIZED **films** showed good mechanical performance and improved UV-barrier and antioxidant properties compared to the control film

After 5 weeks of exposure to organic soil, the FUNCTIONALIZED **films** exhibited 13–16% disintegration

The FUNCTIONALIZED **films** used to package cookies (7 % moisture content) retained their mechanical performance and UV barrier properties over 30-days under both light and dark conditions at 25 ºC and 30 ºC

COOKIES packaged with the FUNCTIONALIZED **film** for 30 days (under both light and dark conditions at 25 ºC and 30 ºC) maintained good appearance, colour, moisture content, and sensory acceptance.

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CONCLUSIONS

Thank you for your attention

Email: emfva@isep.ipp.pt

https://www.isep.ipp.pt/Page/ViewPage/Chestfilm

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Valentina Fernandes Domingues
REQUIMTE/LAQV, ISEP, Polytechnic of Porto
Jointly elaborated by: Aix-Marseille University

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Eco-friendly Bioplastics and Biocomposites – From Chestnut Waste to Green Materials: Part 2

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