Ref. Ares(2026)9068989 - 25/09/2026



HORIZON-CL6-2024-CIRCBIO-01-5

Programmed biodegradation capability of bio-based materials and products, validated in specific environments

MAGICBIOMAT

Manufacturing Guiding Tool for Circular and Programmed Biodegradable Materials Under Open Environment Conditions

Start Date: January 1st, 2025

Duration: 48 Months

Deliverable: D6.1

Prototypes of Agricultural Mulch Films

Due date of deliverable: 30/09/2026

Actual submission date: 25/09/2026

Responsible WP: WP6, Yuanyuan Chen, TUS

Responsible Technical Leader: Yuanyuan Chen, TUS

Revision: V1.0

Dissemination level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Funded by the European Union

Authors

Author	Institution	Contact (e-mail, phone)
Dr Yuanyuan Chen	TUS	Yuanyuan.chen@tus.ie
Dr Ke Gong	TUS	Ke.gong@tus.ie
Dr Golnoosh Abdeali	TUS	Golnoosh.Abdeali@TUS.ie
Zeynep Mert Ayalp	OK	Z_mert@organikkimya.com
Melike OCAK ÖZKAN	OK	M_ozkan@organikkimya.com
Dr Alessandra Lorenzetti	UNIPD	Alessandra.lorenzetti@unipd.it
Lara Facchini	UNIPD	Lara.facchini@phd.unipd.it

Document History

Document version	Date DD/MM/YY	Changes
1.0	07/09/2026	First draft ready for review
2.0	20/09/2026	Final file after the revision

Document Approval

Reviewers		Validation date
Work Package Leader	Dr. Yuanyuan Chen	10/09/2026
Coordinator	Dr. Yuanyuan Chen	23/09/2026

Document Data

Keywords	Mulch film, Biodegradability, Chitosan, Glucose, Mechanical performance, Barrier property
Point of Contact	Name: Yuanyuan Chen Partner: TUS (Coordinator) Address: Technological University of the Shannon, Athlone Campus, University Road, Athlor Westmeath, N37HD68 Phone: +353087766337 E-mail: Yuanyuan.chen@tus.ie
Partner:	TUS, OK, UNIPD

Disclaimer

Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them

Funded by the European Union

Acronyms

AI	Artificial Intelligence
BDMs	Biodegradable Mulch Films
D1.5	Deliverable 1.5
D6.1	Deliverable 6.1
DSC	Differential Scanning Calorimetry
EU	European Union
GA	Grant Agreement
GVP	Gas Vapor Permeability
MD	Machine Direction
PBS	Polybutylene Succinate
PE	Polyethylene
PLA	Polylactic Acid
TD	Transverse Direction
TGA	Thermogravimetric Analysis
TUS	Technological University of the Shannon
T_g	Glass Transition Temperature
T_m	Melting Temperature
UNIPD	University of Padua
WP	Work Package
WP1	Work package 1
WP2	Work package 2
WP6	Work Package 6
WVP	Water Vapor Permeability

Funded by the European Union

Executive Summary

Deliverable (D)6.1 aims to pick biodegradable polymer blends and develop agricultural mulch films with a relatively slow biodegradation behaviour. The work builds on the materials developed and characterised in work package 1 (WP1) from their processability, thermal and mechanical behaviours and biodegradation performance. Based on the results obtained in WP1, candidate formulations were assessed and selected for mulch film purpose. Particular emphasis was placed on materials exhibiting suitable biodegradation behaviour, with approximately 90% biodegradation by Month (M) 4 in industrial composting condition in deliverable 1.5 (D1.5).

One blend from Technological University of the Shannon (TUS) and another one from University of Padova (UNIPD) were subsequently processed into agricultural mulch films, with scale-up targeting film dimensions of up to 20meter length and 40µm thickness. The produced films were characterised in thermal, tensile, and permeability behaviours, which were all relevant to agricultural mulch films. In total 400 specimens (10cm × 3cm) were prepared for accelerated aging test in Task 6.2 and open field biodegradation behaviour in Task 6.3. These specimens will enable assessment of the mulch films under the environmental and application-specific conditions defined in the subsequent tasks and provide a direct link between material development in Task 6.1 and their further performance and degradation evaluation.

D6.1 demonstrates the selection and scale-up development of polyester-based biodegradable mulch films with properties tailored towards agricultural applications and a controlled biodegradation profile. The deliverable establishes the relationship between material formulation, film processability, mechanical and barrier performance, and biodegradation requirements, while providing the representative film specimens required for the subsequent assessment activities under Tasks 6.2 and 6.3.

Funded by the European Union

Table of Contents

Acronyms 3

Executive Summary 4

List of Figures 6

List of Tables 6

1. Introduction 7

2. Methodology 8

2.1. Materials 8

2.2. Hot Melt Extrusion 8

2.3. Film Production 8

2.4. Differential Scanning Calorimetry (DSC) 9

2.5. Thermogravimetric Analysis (TGA) 9

2.6. Tensile Test 9

2.7. Permeability 10

2.7.1. Water Vapor Permeability (WVP) 10

2.7.2. Gas Vapor Permeability (GVP) 10

3. Results 10

3.1. Film Production 10

3.2. DSC 11

3.3. TGA 11

3.4. Tensile Test 12

3.5. Permeability 15

4. Conclusions 16

5. References 17

Funded by the European Union

List of Figures

Figure 1. Film production details: a) material rolling on Calander 1 from die; b) film passing Calander 2; c) film being pulling by Haul-ff section, and d) film consistently produced and collected by the winder. 10

Figure 2. DSC results for UNIPD-PBAT72%PLA5%STARCH20%Plast3% and TUS-PBS76%PLA19%Bioadd5% batches. 11

Figure 3. TGA results for UNIPD-PBAT72%PLA5%STARCH20%Plast3% and TUS-PBS76%PLA19%Bioadd5% batches. 12

Figure 4. Tensile test sample preparation 13

List of Tables

Table 1. Tensile performances of TUS and UNIPD films in function of MD and TD. 13

Table 2. Permeability results of batches from TUS and UNIPD. 15

Funded by the European Union

1. Introduction

The widespread use of plastics has become indispensable in modern society owing to their versatility, low production cost, and excellent processability (MacArthur, 2017). In the agriculture field, plastic mulch films have been extensively adopted because they improve soil moisture retention and enhance crop productivity (Mansoor et al., 2022). However, traditional petroleum-based mulch films, such as polyethylene (PE), exhibit poor degradability and limited recyclability, leading to persistent plastic residues in agricultural soils (Li et al., 2022) and broader environmental contamination (Y. Yang et al., 2022). In response to these challenges, biodegradable mulch films (BDMs) have gained considerable attention as a sustainable alternative capable of providing comparable agricultural performance while reducing environmental burdens through biodegradation after their intended service life.

Workpackage 6 (WP6), long-term degradation application in open environment conditions, aims to evaluate material performance through long-term exposure climatic regions, thereby generating comprehensive datasets that reflect real environmental degradation behaviour. These experimental data will not only support material validation but will also provide the foundation for the development and refinement of artificial intelligence (AI)-based predictive models. Furthermore, the monitoring results generated throughout WP6 will contribute to a deeper understanding of degradation mechanisms and facilitate the calibration and optimisation of the predictive software platform established in WP3.

Task 6.1 serves as the initial stage of WP6 and focuses on the identification, optimisation, and manufacture of biodegradable agricultural mulch films exhibiting controlled and prolonged biodegradation characteristics. Candidate polyester-based composite formulations developed during WP1 and WP2 are assessed using the material selection framework established in WP3 to identify formulations capable of meeting the predefined degradation targets. The selected mulch films are designed to achieve approximately 30% biodegradation after six months, 60% after twelve months, and approximately 90% after twenty-four months under open environmental conditions, while maintaining adequate mechanical performance throughout their intended operational lifetime.

This deliverable (D6.1) presents the work completed under Task 6.1, encompassing the material selection methodology, formulation optimisation, pilot-scale film production, specimen preparation, and the initial physical and functional characterisation of the developed biodegradable mulch films. The findings establish the material platform for the subsequent accelerated aging studies (Task 6.2) and long-term biodegradation investigations (Task 6.3), while simultaneously providing essential experimental data for the continued development, calibration, and validation of the AI-assisted degradation prediction model to be implemented during the later stages of the project.

Funded by the European Union

2. Methodology

2.1. Materials

For the TUS batch, polylactic acid (PLA) in pellet form (LX175; density: 1.24 g/cm^3; T_g: 60.2 °C; T_m: 170.3 °C) was purchased from TotalEnergies Corbion (Germany). Polybutylene succinate (PBS) in pellet form (FD92) was supplied by PTT MCC BIOCHEM Co., Ltd in Thailand. Chitosan was provided by Nuoyuan Biotech Co., Ltd. (Shaanxi, China), and glucose (NCM0241B) was supplied by NEOGEN Company. The bio-additive consisted of 40 wt.% chitosan and 60 wt.% glucose. Prior to processing, all materials were dried overnight at 40 °C to remove residual moisture.

For the UNIPD batch, PLA in granule form was obtained from NatureWorks Ingeo™ Biopolymer 4043D. Polybutylene adipate terephthalate (PBAT) in granule form was obtained from Zhuhai Kingfa - ECOPOND KB100. Corn starch C*Flex 03408 was supplied by Cargill, Italy. Glycerol, 99%, Pharmpur®, was purchased from Scharlab Italia S.r.l., Italy.

The selected TUS blend was decided in combination of known biodegradability result in D1.5 and predicted biodegradability from AI software (WP3), since the suitable biodegradability should reach to 90% after 120 days in industrial composting condition). The selected UNIPD blend was decided by the high tensile elongation and the starch composition based on D1.1. This blend is also being utilised in Task 2.3 and a comparison of durability between the biochar/lignin loaded UNIPD material and virgin UNIPD material will benefit the finalised blend utilised in prototype production within this project.

2.2. Hot Melt Extrusion

The PLA, PBS, chitosan, and glucose were first weighed in the mass ratio of 19:76:2:3 and then compounded using a twin-screw extruder (PRISM TSE 16) to obtain TUS-PBS76%PLA19%Bioadd5% blend. This machine featured a L/D ratio of 15:1, co-rotating intermeshing screws, and a cord-type extrusion die with a 6 mm diameter circular cross-section. The extrusion process was conducted at 150°C and a 100rpm screw rotation speed.

UNIPD-PBAT72%PLA5%STARCH20%Plast3% blend was prepared by using a twin-screw co-rotating extruder (L/D =27); the extrusion was conducted using a temperature profile between 140 and 170°C and a 100rpm screw rotation speed.

2.3. Film Production

To produce the film for D6.1, a MINICAST.K multilayer cast film extruder (EUR.EX.MA, Italy) was utilised. The heating parameters utilised for both TUS and UNIPD blends are shown as follows: temperature for feeding unit 1-B, 2-B, 3-

Funded by the European Union

B are145°C, 150°C, and 155°C, respectively; temperature for box, 1-H, 2-H of die and lip are 160°C, 160°C, 150°C, and 160°C, respectively.

Meanwhile, the film thickness can be varied in function of the settings in feeding rate, calander, haul-off, and winder. For example, the TUS-PLA19-PBS76-C2-G3 films with 40, 30, 20μm thickness were obtained using the following settings: feeding rate (80rpm), Calander 1 (1, 2, 4Mt/min), Calander 2 (1, 2, 4Mt/min), Haul-off (1.2, 2.2, 4.4Mt/min), and Winder (15%).

Regarding the UNIPD-PBAT72%PLA5%STARCH20%Plast3% ones, films with 40, 30, 20μm thickness were obtained using the following settings: Calander 1 (1, 2, 4Mt/min), Calander 2 (1, 2, 4Mt/min), Haul-off (1.2, 2.2, 4.2Mt/min), and Winder (15%).

2.4. Differential Scanning Calorimetry (DSC)

The DSC test was carried out using a 214 polyma (NETZSCH) machine to determine the thermal performances. This allows for a comparison between the characterisations of polymer obtained in D1.1 and D6.1. These granule samples were placed in crimped aluminium pans prior to the tests, with an empty crimped aluminium pan employed as a reference batch. The DSC tests consisted of three-stage experiments, starting from 20°C and reaching 200°C in the rate of 10°C/min, dropping to -80°C in the rate of 10°C/min, and increasing 200°C in the rate of 10°C/min.

2.5. Thermogravimetric Analysis (TGA)

TGA was performed to determine the thermal degradation behaviour of all PLA batches. It was conducted using a TGA 8000 thermogravimetric analyser (PerkinElmer, Shelton, CT, USA) under a nitrogen atmosphere to prevent oxidative degradation during heating. Under nitrogen flow, samples with roughly 15mg were heated from room temperature to 700°C at a heating rate of 15°C/min. The mass loss curves and derivative thermogravimetric curves were recorded and analysed.

2.6. Tensile Test

The tensile strength, Young's Modulus, and elongation at break of the TUS-PLA19-PBS76-C2-G3 film and UNIPD film were investigated using a Lloyd LRX Universal Testing Machine (Lloyd Instruments Ltd., Bognor Regis, UK) with a 2.5kN load cell at room temperature. In the tensile test, the samples were cut into dog bone shapes (the centre street zone of 20mm length and 4.5mm width based on ISO527-3 Standard), and a crosshead speed of 50mm/min was utilised during the measurement. Each batch was measured in both machine direction (MD) and transverse direction (TD) with 5 replicates.

Funded by the European Union

2.7. Permeability

2.7.1. Water Vapor Permeability (WVP)

The WVP of both TUS and UNIPD films with thickness ranging from 30 to 40µm were determined in the condition of 23°C and relative humidity of 90% using Extra Solutions Perme H_2O Water Vapor Transmission Rate Permeability Tester according to ISO 15106, with three replicates for each batch.

2.7.2. Gas Vapor Permeability (GVP)

The GVP (carbon dioxide, CO_2) of both TUS and UNIPD films with thickness ranging from 30 to 40µm were determined in the condition of 23°C using Extra Solutions Perme CO_2 Vapor Transmission Rate Permeability Tester, followed by ASTM D1434-82. The results were averaged from three parallel samples of each film.

3. Results and discussion

3.1. Film Production

The TUS-PBS76%PLA19%Bioadd5% and UNIPD-PBAT72%PLA5%STARCH20%Plast3% pellets were successfully cast into films with different thickness (20, 30, and 40µm). Below Figure 1 exhibits the production details for TUS-PBS76%PLA19%Bioadd5% film. The films were produced at a width of 20 cm, corresponding to the maximum processing width of the film production equipment, and a thickness of 40µm. A continuous film length of up to 30 meter was produced and subsequently cut into 400 strips, each measuring 10×3cm. The first 200 strips will be performed in accelerated aging test in TUS (Task 6.2) from M21 and another 200 strips will be sent to ISOTECH for open field biodegradation test (Task 6.3) in M21.



Figure 1. Film production details: a) material rolling on Calander 1 from die; b) film passing Calander 2; c) film being pulling by Haul-ff section, and d) film consistently produced and collected by the winder.

Funded by the European Union

3.2. DSC

Below Figure 2 displays the DSC curves and T_g and T_m values for the batches from TUS and UNIPD. It can be seen that the T_g of UNIPD-PBAT72%PLA5%STARCH20%Plast3% finds a higher value (-31°C) than that shown in D1.1 (~ -36°C). This behaviour can be explained from the different equipment utilised between D1.1 and D6.1, where a more accurate loading and composition ratio was achieved here in D6.1. Similarly, two melting peaks can be found for this batch, which refer to PBAT (120.1°C) and PLA (148.1°C).

As for the TUS-PBS76%PLA19%Bioadd5%, similar phenomenon can be noticed for dual T_m peaks (87.1°C for PBS and 146.9°C for PLA). The T_g is valued at -43.5°C, which finds similarly to D1.1.

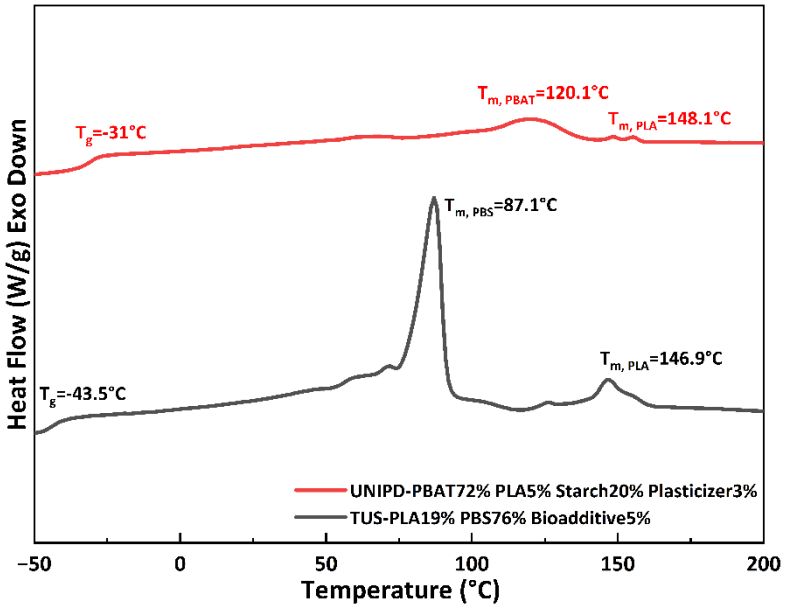


Figure 2. DSC results for UNIPD-PBAT72%PLA5%STARCH20%Plast3% and TUS-PBS76%PLA19%Bioadd5% batches.

3.3. TGA

The TGA curves shown in Figure 3 find both formulations undergo their principal thermal decomposition between approximately 330 and 430°C, indicating that degradation is primarily governed by decomposition of the biodegradable polyester matrix. Before the main degradation stage, both samples retain most of their initial mass, although the UNIPD-PBAT72%PLA5%Starch20%Plasticizer3% exhibits an earlier and more noticeable weight loss beginning at approximately 280 to 300°C. In contrast, TUS-PLA19%PBS76%bioadditive5% maintains a relatively stable mass until around 320 to 330°C, suggesting comparatively better thermal stability at intermediate temperatures.

A further difference is apparent after the main degradation stage. The UNIPD-PBAT72%PLA5%Starch20%Plasticizer3% retains approximately 7 to 8% residual mass at ~430 °C, followed by gradual decomposition between approximately 450 and 580°C. This secondary region may arise from the

Funded by the European Union

decomposition of carbonaceous residues generated from starch and/or thermally stable fractions associated with the formulation. Conversely, the TUS-PLA19%PBS76%bioadditive5% decreases rapidly to only a few percent residue after approximately 430°C, with the remaining material disappearing at a somewhat lower temperature.

Overall, the TGA results indicate that TUS-PLA19%/PBS76%/bioadditive5% exhibits greater initial thermal stability, whereas incorporation of 20% starch and 3% plasticizer in the UNIPD formulation promotes earlier multistage thermal degradation. Nevertheless, both formulations remain comparatively stable well above typical melt-processing temperatures, suggesting an adequate thermal processing window provided that prolonged exposure to elevated temperatures is avoided.

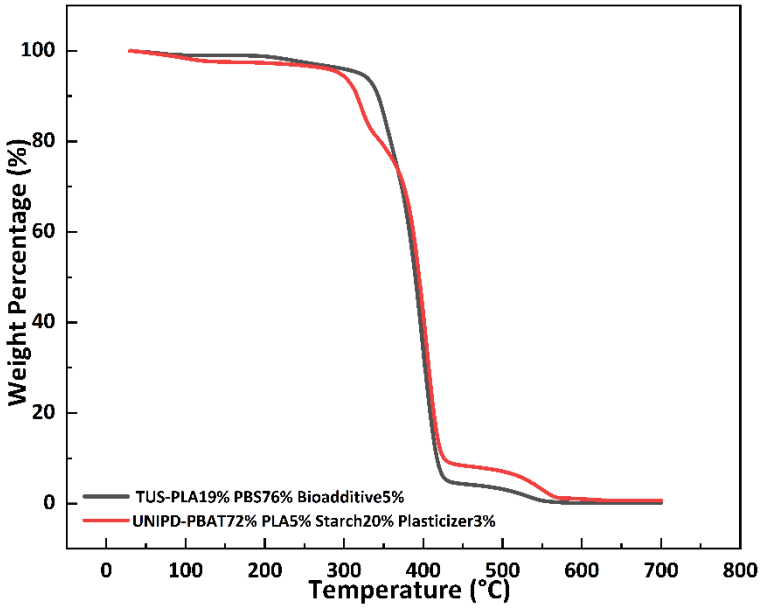


Figure 3. TGA results for UNIPD-PBAT72%PLA5%STARCH20%Plast3% and TUS-PBS76%PLA19%Bioadd5% batches.

Tensile Test

After the cast film production, standard tensile test samples were punched out at both Machine Direction (MD) and Transverse Direction (TD), as shown in image below.

Funded by the European Union

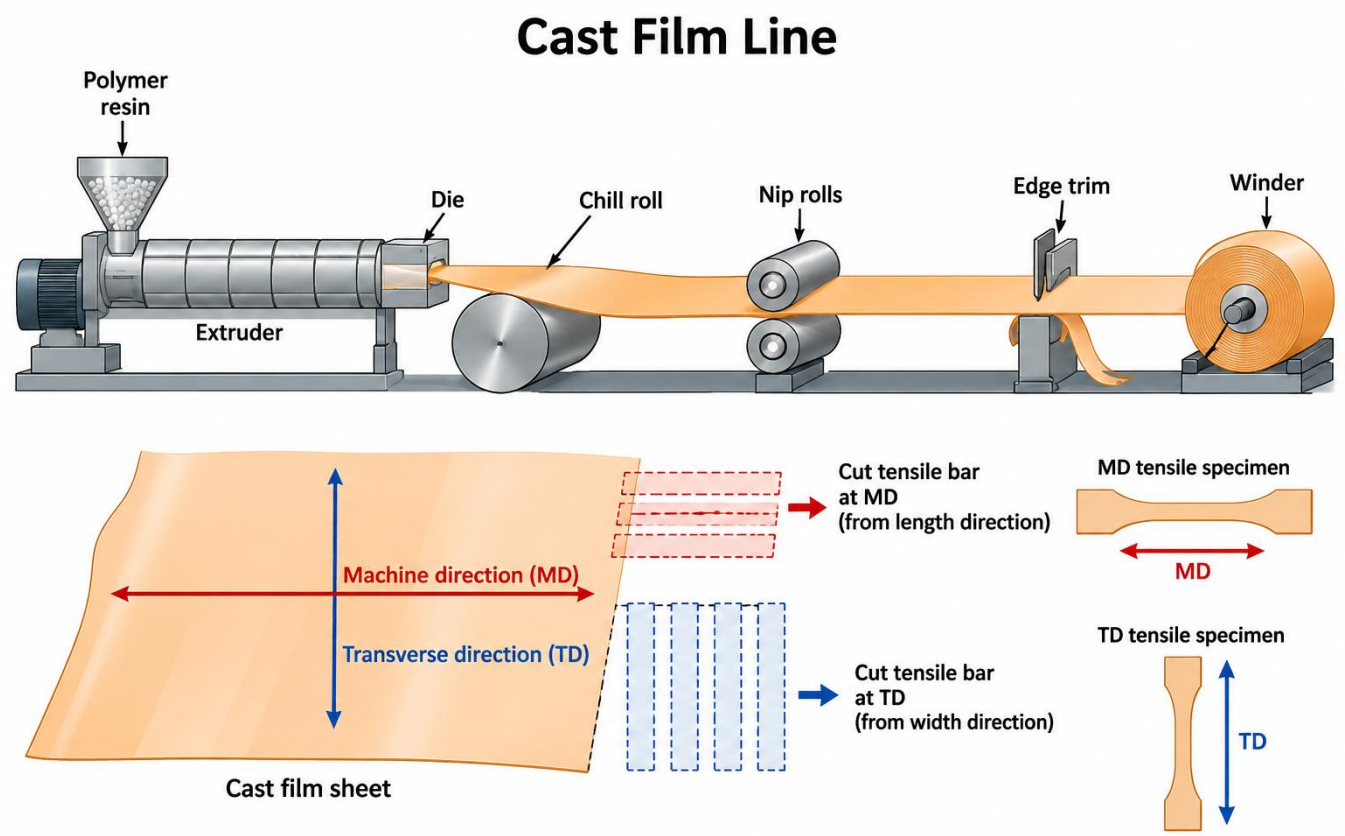


Figure 4. Tensile test sample preparation

The tensile performances (MD and TD) of both TUS-PBS76%PLA19%Bioadd5% and UNIPD-PBAT72%PLA5%STARCH20%Plast3% are shown in Table 1. The tensile strengths (MD) of both TUS-PBS76%PLA19%Bioadd5% (26.1±2.2MPa) and UNIPD-PBAT72%PLA5%STARCH20%Plast3% (33.4±1.5MPa) films are greater than 18MPa and the tensile strengths (TD) of both TUS-PBS76%PLA19%Bioadd5% (22.5±1.7MPa) and UNIPD-PBAT72%PLA5%STARCH20%Plast3% (25.4±3.6MPa) films are greater than 16MPa, which are all in line with EN17033: 2018. Regarding the elongation, the TUS-PBS76%PLA19%Bioadd5% finds a 298.0±103.4% and 225.9±76.9% for MD and TD, respectively. As for the UNIPD-PBAT72%PLA5%STARCH20%Plast3%, the elongation for MD and TD are 816.1±38.4% and 665.1±109.8%, respectively. This result may be resulted from the limited length of gauge (20mm) and width (4.5mm). As for the Young's Modulus, the values for MD (466.1±56.6MPa for TUS-PBS76%PLA19%Bioadd5% and 175.9±8.3MPa for UNIPD-PBAT72%PLA5%STARCH20%Plast3%) are always greater than those for TD (374.8±25.3MPa for TUS-PBS76%PLA19%Bioadd5% and 173.1±6.3MPa for UNIPD-PBAT72%PLA5%STARCH20%Plast3%).

Table 1. Tensile performances of TUS and UNIPD films in function of MD and TD.

Batch	Tensile Strength (MPa)	Young's Modulus (MPa)	Elongation (%)EN 17033:2018 - Biodegradable Mulch Films for Agriculture

Funded by the European Union

			Standards (n.d.)
TUS-PBS76%PLA19%Bioadd5%-MD	26.1±2.2	466.1±56.6	298.0±103.4
TUS-PBS76%PLA19%Bioadd5%-TD	22.5±1.7	374.8±25.3	225.9±76.9
UNIPD-PBAT72%PLA5%STARCH20%Plast3%-MD	33.4±1.5	175.9±8.3	816.1±38.4
UNIPD-PBAT72%PLA5%STARCH20%Plast3%-TD	25.4±3.6	173.1±6.3	665.1±109.8

EN 17033:2018 is the relevant European standard for thermoplastic biodegradable mulch films intended to biodegrade in soil. It sets minimum tensile stress at break and strain-at-break requirements that vary with film thickness. The most demanding listed tensile-strength threshold is 18 MPa, while elongation requirements can reach 200% MD and 350% TD, depending on thickness category (*EN 17033:2018 - Biodegradable Mulch Films for Agriculture Standards*, 2018). The tensile performance of some common biodegradable mulch film is listed below.

Film	**Strength (MPa)**	**Modulus (MPa)**	**Elongation (%)**	**Assessment**
TUS-PBS76%PLA19%Bioadd5%-MD	26.1	466	298	Good
TUS-PBS76%PLA19%Bioadd5%-TD	22.5	375	226	Good, but TD elongation needs attention depending on thickness class
UNIPD-PBAT72%PLA5%STARCH20%Plast3%-MD	33.4	176	816	Excellent ductility
UNIPD-PBAT72%PLA5%STARCH20%Plast3%-TD	25.4	173	665	Excellent ductility
Typical neat PBAT (Yu et al., 2024)	~15–36	relatively low	>700	Common biodegradable mulch polymer
Recent PBAT multilayer mulch (Montoneri et al., 2026)	~24–25	—	~520–570	Demonstrated agricultural film
PBAT/lignin mulch (Z. Liu et al., 2025)	22.4	—	252	Reported mulch-film formulation

The film developed by TUS (PBS76%/PLA19%/Bioadd5%) exhibited a good balance between strength, stiffness and ductility. Tensile strengths of 26.1 MPa (MD) and 22.5 MPa (TD), together with elongations of 298% and 226%,

Funded by the European Union

respectively, demonstrate substantially greater flexibility and extensibility than typically expected from brittle PLA-rich films. Its relatively high Young's modulus (466 MPa MD and 375 MPa TD) indicates greater stiffness and dimensional stability, which may be advantageous for maintaining film integrity during handling and field application.

In comparison, the UNIPD film (PBAT72%/PLA5%/starch20%/plasticizer3%) exhibited higher tensile strength (33.4 MPa MD and 25.4 MPa TD) combined with exceptionally high elongation (816% and 665%), but a considerably lower Young's modulus of approximately 173–176 MPa. This behaviour is consistent with the high PBAT content and indicates a softer, highly flexible and deformation-tolerant film. Such high ductility may reduce the risk of premature tearing during mulch-film installation and field use.

Overall, the two formulations provide distinct but potentially suitable mechanical profiles for agricultural mulch applications: the TUS film offers greater stiffness with good strength and extensibility, whereas the UNIPD film provides greater flexibility and substantially higher elongation.

3.4. Permeability

The WVP and GVP results of TUS and UNIPD batches are shown in Table 2. Similar behaviours can be noticed in both batches. The UNIPD batch shows an approximately 15.7% lower WVP than the TUS one, indicating moderately improved resistance to moisture transmission. Such difference is likely associated with the combined effects of polymer composition, phase morphology, crystallinity and the additives. A slightly different trend was obtained for GVP: TUS-PBS76%PLA19%Bioadd5% exhibits a GVP of 1013.59±77.51 $cm^3/(m^2 \cdot 24\ h)$, while the UNIPD one finds a 1067.17±38.64 $cm^3/(m^2 \cdot 24\ h)$. The latter value is approximately 5.3% higher, indicating slightly poorer resistance to gas transmission. However, this difference is relatively small compared with that observed for WVP, particularly considering the standard deviation for TUS batch.

Table 2. Permeability results of batches from TUS and UNIPD.

Batch	WVP [$g/(m^2/24h)$]	GVP [$cm^3/(m^2*24h)$]
TUS-PBS76%PLA19%Bioadd5%	26.84±1.64	1013.59±77.51
UNIPD-PBAT72%PLA5%STARCH20%Plast3%	22.63±1.80	1067.17±38.64

The current European standard EN 17033:2018 for biodegradable mulch films specifies requirements covering material, biodegradation/ecotoxicity, dimensional, mechanical and optical properties, but it does not prescribe a single maximum WVTR or CO_2TR. However, published results provided a useful benchmark:

Mulch film	**Typical/Reported WVTR, $g/(m^2 \cdot day)$**	**Interpretation**
Conventional PE	<50	Excellent moisture barrier

Funded by the European Union

PCL biodegradable film	~786	High water transmission
PBAT biodegradable film	~890	High water transmission
PBAT-based biodegradable films	~900	Barrier deteriorates during degradation
TUS-PBS76%PLA19%Bioadd5%	26.84 ± 1.64	Very good
UNIPD-PBAT72%PLA5%STARCH20%Plast3%	22.63 ± 1.80	Very good

One study measured approximately 50 g/m^2/day for a ~10.8 µm PE mulch film, compared with 637–890 g/m^2/day for biodegradable PCL/PBAT films under its test conditions(N. Yang et al., 2022). Another field study similarly found PE remained below 50 g/m^2/day, while PBAT-based biodegradable films had substantially higher WVTR that increased as the films degraded (Q. Liu et al., 2022).

Mulch film does not require the extremely low CO_2 transmission associated with high-barrier food packaging. Soil continues to respire, and gas exchange is part of the mulch/soil system. Therefore, CO_2 transmission is usually not assessed unless for a specific crop application.

In Short, both of our films showed moderate water-vapour barrier combined with relatively high CO_2 permeability, which can be suitable for agricultural mulch applications.

4. Conclusions

In this D6.1, two blends, one from UNIPD (UNIPD-PBAT72%PLA5%STARCH20%Plast3%) and one from TUS (TUS-PBS76%PLA19%Bioadd5%), are selected to produce mulch films. Raw materials are first compounded for blends and then utilised in cast film purpose. The thermal, mechanical, and permeability results of both batches are all determined to figure out their possibility for mulch film application.

The thermal behaviours of both batches find both of them remain comparatively stable well above the processing temperature (160°C), suggesting an adequate thermal processing window provided that prolonged exposure to elevated temperatures is avoided. The tensile behaviours show that both of them have achieved promising characterisations for mulch film purpose based on EN17033. The permeability results find different phenomena, where a lower WVP but a higher GVP can be found in UNIPD blend. This indicates that polymer composition is a critical parameter affecting the permeability behaviour.

Funded by the European Union

Apart from the characterisations shown as above, the higher biodegradability shown in D1.5 reveals TUS-PBS76%PLA19%Bioadd5% should be picked in the mulch film application. Therefore, this blend had been utilised to fabricate film and cut into 400 strips for Task 6.2 (aging test performed in TUS) and 6.3 (open field biodegradation test in ISOTECH). Another 5wt.% enzyme carrier is intended to further investigate its influence on the biodegradation behaviour and overall performance of the mulch films under both accelerated aging and open-field conditions, particularly given the enhanced biodegradability previously observed for the enzyme-loaded TUS in D1.5. Evaluation of this optimised formulation will expand the database for the AI software, thereby improving the representation of enzyme-loaded biodegradable materials and supporting the future prediction and optimisation of their performance under relevant environmental conditions.

References

EN 17033:2018 - Biodegradable Mulch Films for Agriculture Standards. (n.d.). Retrieved September 24, 2026, from https://standards.iteh.ai/catalog/standards/cen/b09b1982-efd3-45fe-9d87-7798699e5c3c/en-17033-2018?utm_source=chatgpt.com

EN 17033:2018 - Biodegradable Mulch Films for Agriculture Standards. (2018). https://standards.iteh.ai/catalog/standards/cen/b09b1982-efd3-45fe-9d87-7798699e5c3c/en-17033-2018?utm_source=chatgpt.com

Li, S., Ding, F., Flury, M., Wang, Z., Xu, L., Li, S., Jones, D. L., & Wang, J. (2022). Macro- and microplastic accumulation in soil after 32 years of plastic film mulching. *Environmental Pollution*, *300*. https://doi.org/10.1016/j.envpol.2022.118945

Liu, Q., Wang, Y., Liu, J., Liu, X., Dong, Y., Huang, X., Zhen, Z., Lv, J., & He, W. (2022). Degradability and Properties of PBAT-Based Biodegradable Mulch Films in Field and Their Effects on Cotton Planting. *Polymers*, *14*(15), 3157. https://doi.org/10.3390/POLYM14153157/S1

Liu, Z., Li, Z., Jiang, J., Meng, J., & Qin, H. (2025). Biodegradable and Multifunctional PBAT/Lignin Mulch Films for Green Agriculture. *ACS Applied Polymer Materials*, *7*(16), 10711–10720. https://doi.org/10.1021/ACSAPM.5C01964

MacArthur, E. (2017). Beyond plastic waste. *Science*, *358*(6365), 843. https://doi.org/10.1126/science.aao6749

Mansoor, Z., Tchuenbou-Magaia, F., Kowalczuk, M., Adamus, G., Manning, G., Parati, M., Radecka, I., & Khan, H. (2022). Polymers Use as Mulch Films in Agriculture—A Review of History, Problems and Current Trends. *Polymers*, *14*(23). https://doi.org/10.3390/polym14235062

Montoneri, E., Evon, P., Charbonnier, J., La Bella, E., Fragalà, F., Puglisi, I., Baglieri, A., Labonne, L., Jégat, L., Mendez, S., Solaro, S., Padoan, E., & Diéguez, J. L. (2026). Mulch Films Manufactured from Poly(Butylene Adipate-Co-Terephthalate) and Biopolymers Obtained from Urban and Agriculture

Funded by the European Union

Wastes: Mechanical Properties and Effects in Agriculture. *Polymers*, *18*(12), 1550. https://doi.org/10.3390/POLYM18121550

Yang, N., Ying, L., Li, K., Chen, F., Zhao, F., Sun, Z., Feng, L., & Liu, J. (2022). Biodegradable Mulching Films Based on Polycaprolactone and Its Porous Structure Construction. *Polymers*, *14*(24), 5340. https://doi.org/10.3390/POLYM14245340

Yang, Y., Li, Z., Yan, C., Chadwick, D., Jones, D. L., Liu, E., Liu, Q., Bai, R., & He, W. (2022). Kinetics of microplastic generation from different types of mulch films in agricultural soil. *Science of the Total Environment*, *814*. https://doi.org/10.1016/j.scitotenv.2021.152572

Yu, Y., Velandia, M., Hayes, D. G., Devetter, L. W., Miles, C. A., & Flury, M. (2024). *Biodegradable plastics as alternatives for polyethylene mulch films*. https://doi.org/10.1016/bs.agron.2023.10.003

Funded by the European Union