RECOVER

Development of innovative biotic symbiosis for plastic biodegradation and synthesis to solve their end-of-life challenges in the agriculture and food industries

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17th June 2022, Pisa

This project has received funding from the Bio Based Industries Joint Undertaking (JU) under grant agreement No 837863. The JU receives support from the European Union's Horizon 2020 research and innovation programme and the Bio Based Industries Consortium.

Outline

- The Project figures & the Consortium
- Agri-food Waste Plastics – A global concern
- RECOVER solutions and innovations
- Expected impacts

48 Months

17 Partners

7 Countries (Belgium, Germany, Ireland, Italy, Portugal, Spain, United Kingdom)

5.8 Million € (ca. 4.4 M€ EC contribution)

Call: **BBI-2019-SO2-R3** - Apply microorganisms and/or enzymes to resolve end-of-life issues of plastics

Enzymes + microorganisms + insects + earthworms
Plastics for food packaging and agriculture

Project consortium

Participant name	Short name
Universidad De Almería	UAL (Coo.)
Università Di Pisa	UNIPI
Asociación Agraria Jóvenes Agricultores España	ASAJA
BRUNEL University	BRUNEL
Universidad Miguel Hernández De Elche	UMH
Albstadt-Sigmaringen University	ASU
NATURPLÁS PLÁSTICOS AGRICOLAS, S.L.	NATURPLAS
ASA SPEZIALENZYME GMBH	ASA
NUTRINSECT SRL	NUTRINSECT
IRIS Technology Solutions, S.L.	IRIS
Organic Waste Systems N.V	OWS
IDELUX Environnement	IDELUX
FEMTO ENGINEERING SRL	FEMTO
Ingredient Odyssey LDA - Entogreen	ENTO
CARTON BROS. - MANOR FARM	MANOR
ENCO ENGINEERING SRL	ENCO
S.A. Agricultores de la Vega de Valencia	SAV

5 HES, 1 Association, 1 NGO, 7 SMEs, 3 large enterprises (2 BIC members)

Plastic waste issue

PP

Food packaging, sweet and snack wrappers, hinged caps, microwave containers, pipes, automotive parts, bank notes, etc.

PE-LD / PE-LLD

Reusable bags, frays and containers, agricultural film, food packaging film, etc.

PE-HD / PE-MD

Toys, milk bottles, shampoo bottles, pipes, houseware, etc.

PVC

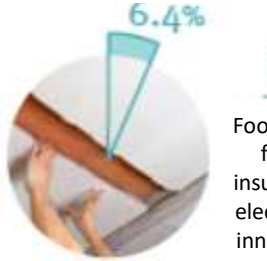
Window frames, profiles, floor and wall cover pipes, cable insulation, garden hoses, inflata pools, etc.

PUR

Building insulation, pillows and mattresses, insulating foams for fridges, etc.

PET

Bottles for water, soft drink, juices, cleaners, etc.



PS / EPS

Food packaging (dairy, fishery), building insulation, electrical & electronic equipment, inner liner for fridges, eyeglasses frames, etc.

OTHERS

Hub caps (ABS), optical fibres (PBT), eyeglasses lenses, roofing sheets (PC), touch screens (PMMA), cable coating in telecommunications (PTFE), and many others in aerospace, medical implants, surgical devices, membranes, valves and seals, protective coatings, etc.

Plastic in agriculture

Protected cultivation films:	**Nets:**	**Packaging:**
• Greenhouse and tunnel	• Anti-hail	• Fertilizer sacks
• Low tunnel	• Anti-bird	• Agrochemical cans
• Mulching	• Wind breaking	• Containers
• Nursery films	• Shading	• Tanks for liquid storage
• Direct covering	• Nets for olives and nut picking	• Crates
• Covering vineyards and orchards	**Piping, irrigation /drainage:**	**Other:**
	• Water reservoir	• Silage films
	• Channel lining	• Fumigation films
	• Irrigation tapes and pipes	• Bale twines
	• Drainage pipes	• Bale wraps
	• Microirrigation	• Nursery pots
	• Drippers	• Strings and ropes

A wide range of plastics are used in agriculture, including, polyolefins (polyethylenes (PE), Polypropylene (PP), Polystirene, Ethylene-Vinyl Accetate Copolymer (EVA) and less frequently, Poly-vinyl chloride (PVC), Polycarbonate (PC) and poly-methyl-methacrylate (PMMA).

Source: https://www.plasticseurope.org/en/about-plastics/agriculture

Agri-food Waste Plastics

Food packaging and Agriculture consume ~44% of worldwide production of plastics

Polyethylenes (PE), Polystyrene (PS), Polyethylenthereptalate (PET)

End of life

Sorting

Waste Management Systems

Plastics

31 % recycled

Non-recyclable: Mixed or multilaminated → Incinerated Landfiled

New RECOVER biorecycling routes

Organic fraction +plastics

Compost contamination

Released to the environment

Soil contamination

Solution

Recover solutions & innovations

Agri-food Waste Plastics (AWPs)

Combining new enzymes, microorganisms, insects & earthworms

Products

Added value products

Fraction	Product	Applications
Chitin from insect	**Chitin-based bioplastics**	Agriculture (pots, plant tips, etc)
		Food packaging
		Enhanced mulching films
Organic leftovers after chitin extraction	**Biofertilizer**	Agriculture
Vermicompost after plastic removal	**Improved Vermicompost**	Agriculture

Processes

- Processes for **AWP biodegradation in soil and compost**
- RECOVER cascade process for safe and sustainable **AWP processing**
- Novel **method for chitin extraction**

Project actions and innovations

Problem: Quantify, characterize, define collection strategy, and pre-treatment

AWPs: Agricultural plastics in soils, non-recyclable food packaging plastics (MSW) and microplastics in compost

Tool: Select & upscale the production of **biotech** solutions

Solution: Upscale and monitor biodegradation capacities

In situ - Bioremediation: Soil
Ex situ - Treatment: Compost & Vermicompost
Insect rearing

Value: Develop added value downstream products

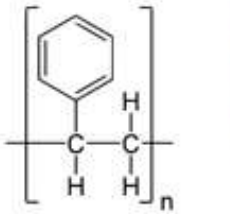
Improved biofertilizers
Chitin-based bioplastics and coatings

Sustainability: Risks, safety, environmental impact, costs, logistic and cascade strategy

LCA & LCC & SLCA and C-foot print

Social, Scientific and Economical **impact**

Recover solutions & innovations



Polystyrene

Yang et al. (2015). Environ Sci Technol, 49, 12080

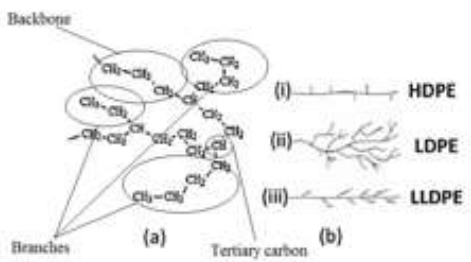
Earthworms & Insects (+microbiome)

Casts/faeces

CO_2

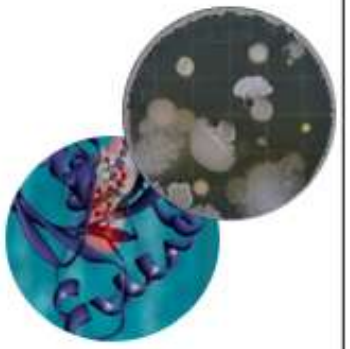
Partial biodegradation

AWP-adapted

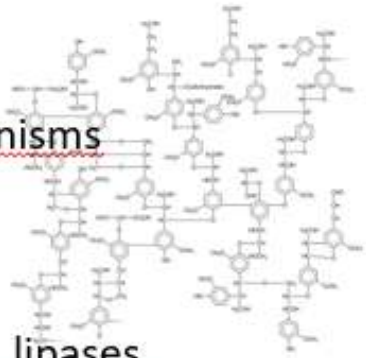


Polyethylene

Sen & Raut (2015) J. Environ. Chem. Eng., 3, 462–473



Microorganisms (Lignin)



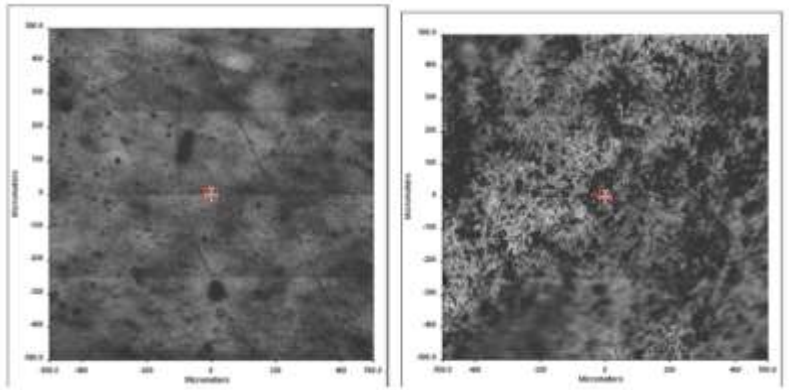
Enzymes (esterases, lipases, hydrolases)

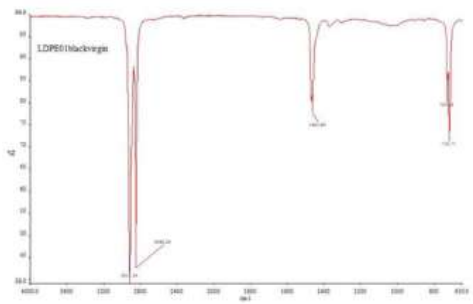
Consortia "ad hoc"

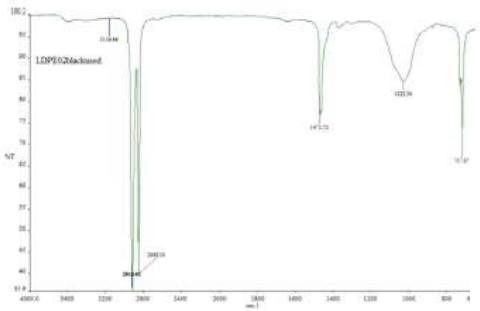
Enzymes "better than nature"

$CO_2 + H_2O$

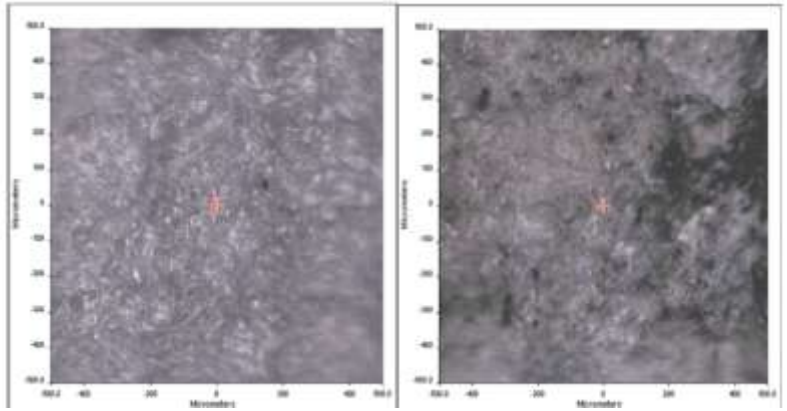
Recover plastic samples

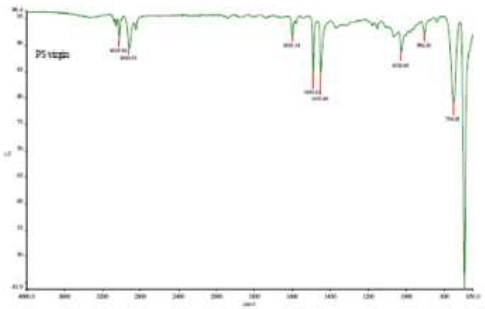


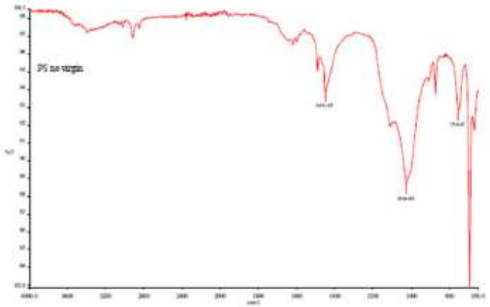




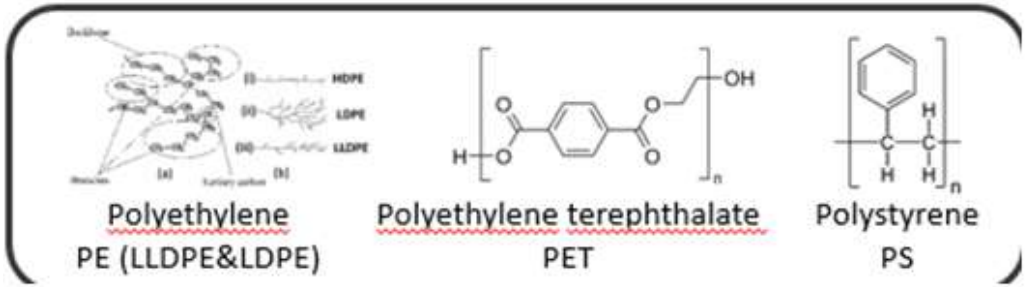
Polyethylene PE, Virgin, used

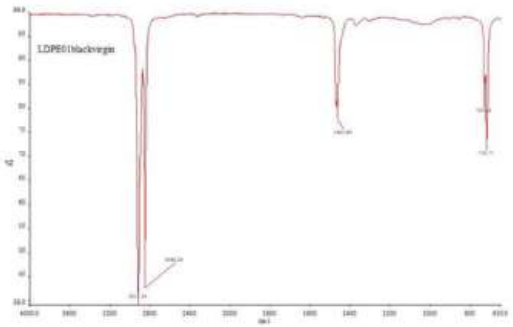


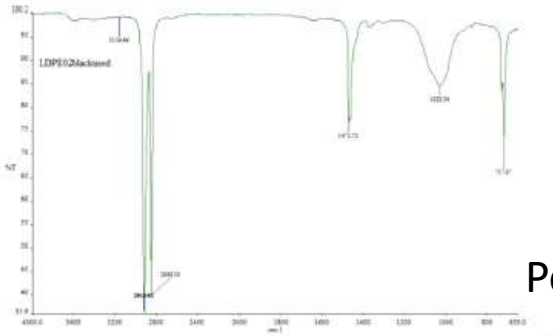




Polystyrene PS, Virgin, used

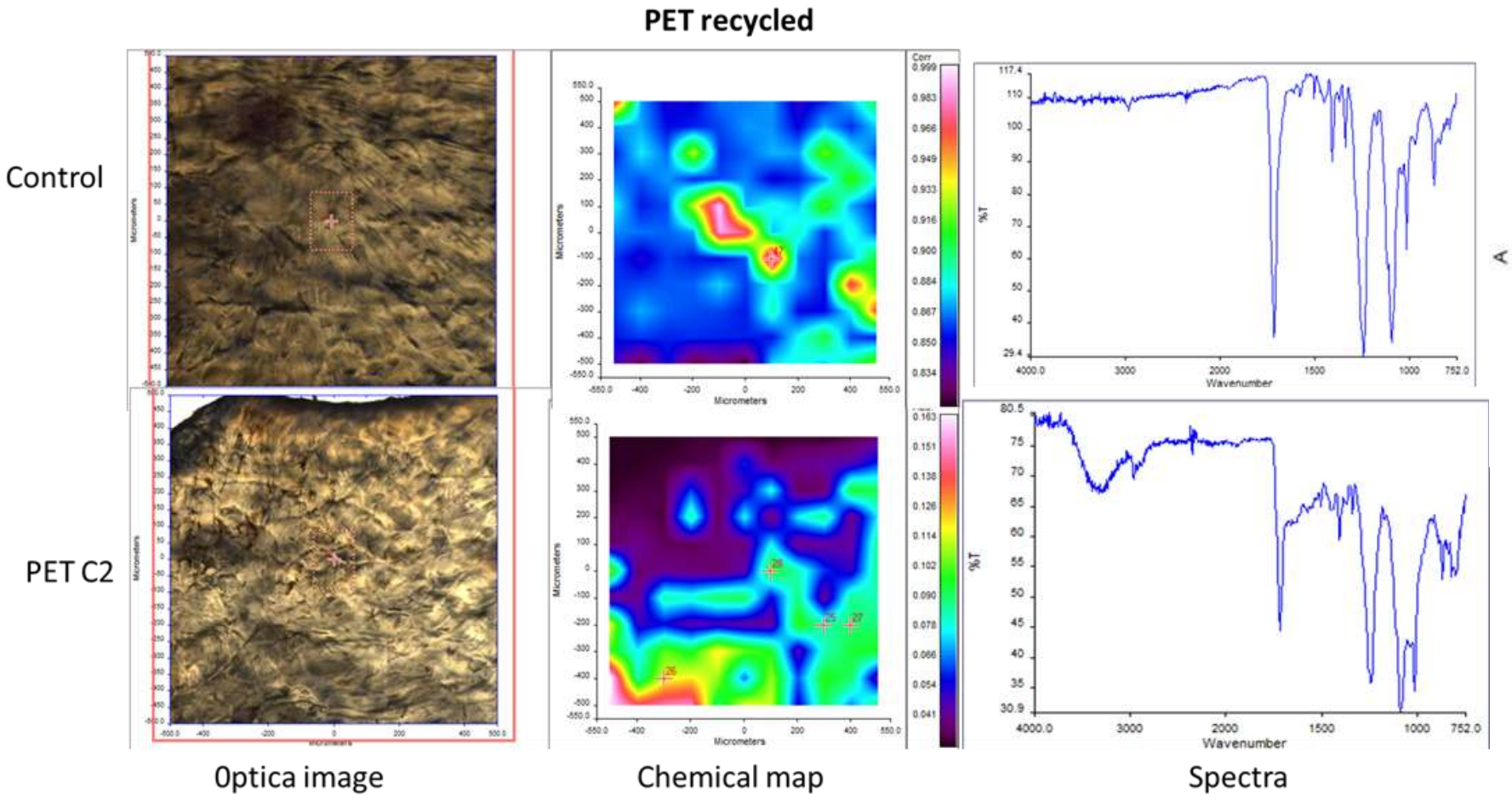


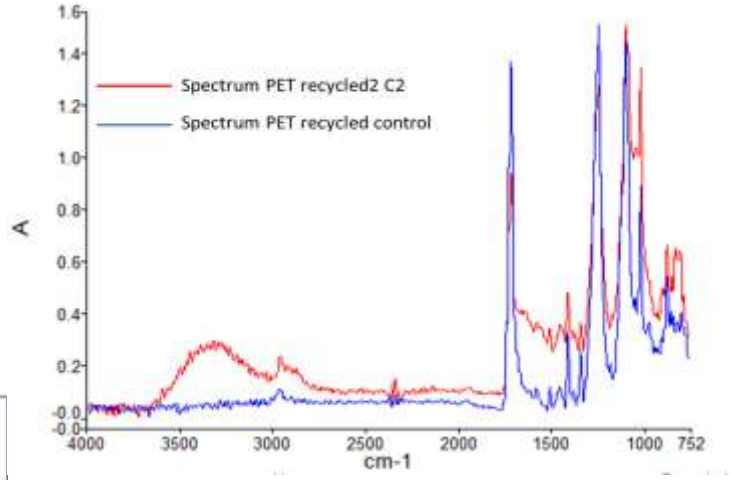




Polyethylene terephthalate PET, Virgin, used

Effect of Pre-Treatments

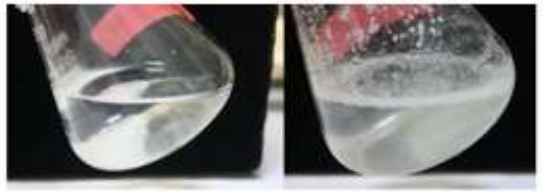




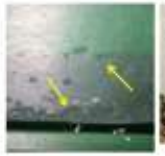
Surface PET chain scission through the hydrolysis of the ester bond

Recover solutions & innovations

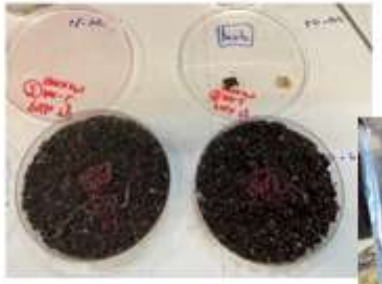
Tool: Select & upscale the production of biotech solutions



Microbial Consortia



Insects



Earthworms

Combination of biocatalytic systems (hydrolytic enzymes, microbial, insects, and earthworms)

- maximize the transformation yields
- allowing the treatment of mixed plastic waste streams
- to convert fossil fuel plastic into biodegradable counterparts in a single step.

Galleria mellonella

Gm-C Gm-PEV-90 Gm-PSR-90

Tenebrio monitor
"Yellow mealworm"

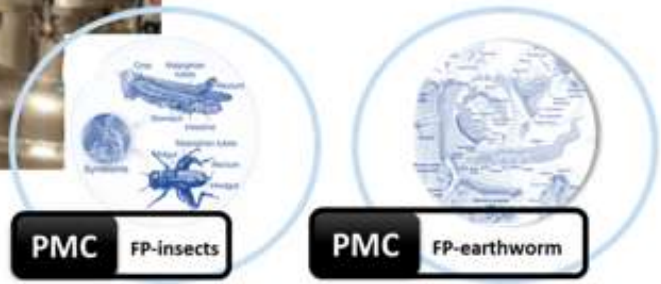
Galleria melonella
"Greater wax moth"

Hermetia illuscens
"Black soldier fly"

E. andrei/foetida

L. terrestris

Upscale and monitor biodegradation capacities



Chitin extraction from exoskeleton of arthropodes

Crabs

Shrimps

Griding

Chemical extraction

Dilute aqueous HCL solution

Decalcification

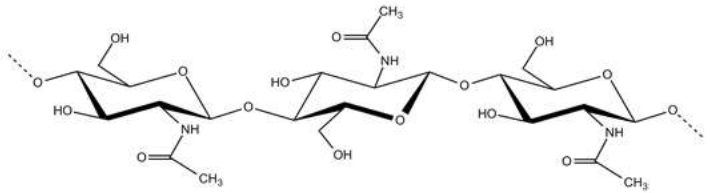
Biological extraction

Proteases producing bacteria

Deproteination

Decolorization

Chitin

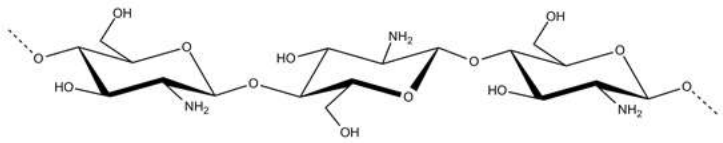


Deacetylation

Hot concentrated NaOH solution (40-50%)

Chitin deacetylase

Chitosan



Non-toxicity, biodegradability, film-forming capacity, **antimicrobial and antioxidant properties**

Extraction

Green process

Chitin/Chitosan

- Pots, sticks or packaging
- Enhanced mulching films
- Food trays, rigid containers, films
- Chitin/chitosan coated films

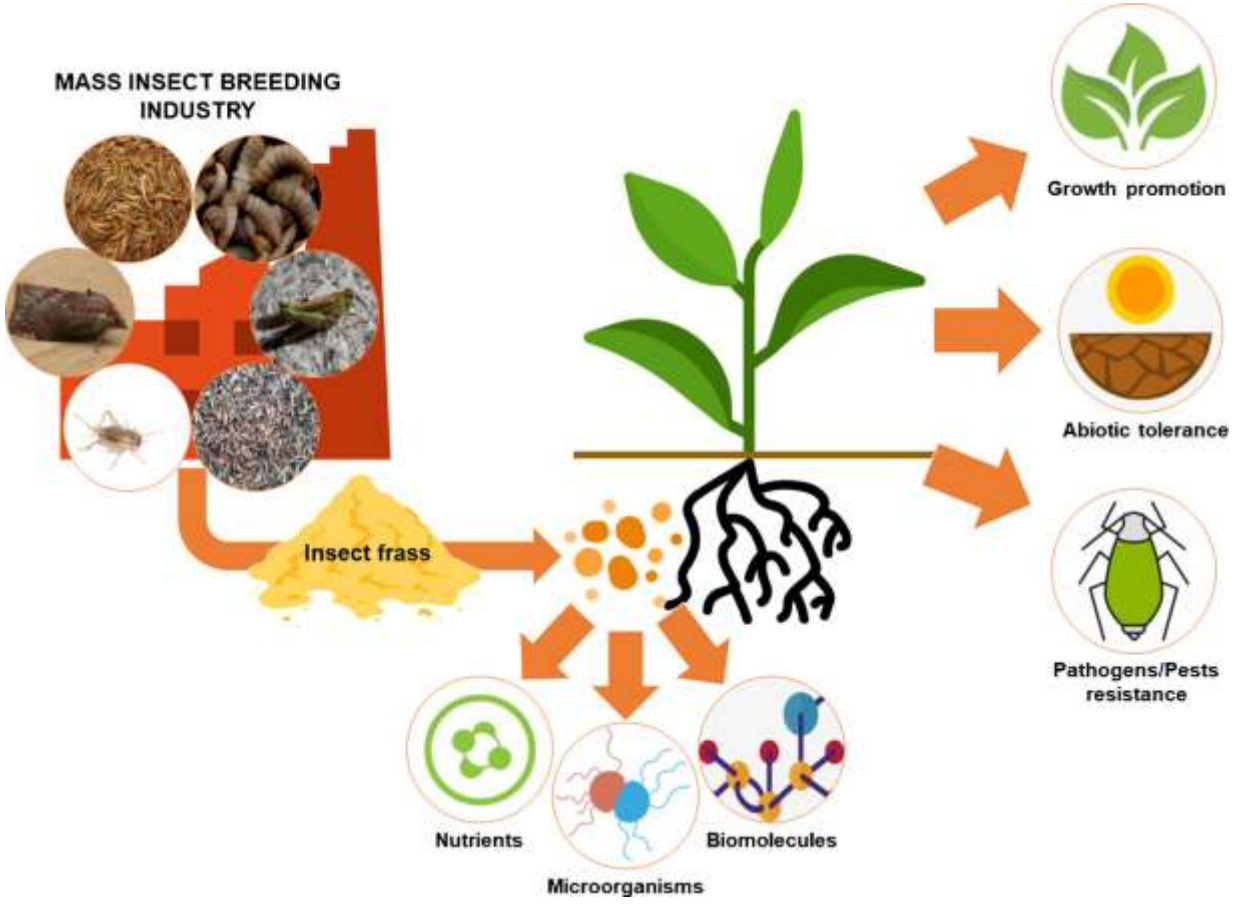
To develop added value downstream products

Biofertilizers from insect frass

Waste treatment	pH	EC (dS/m)	Moisture (%)	C (%)	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Reference
Mealworm	–	–	–	38.9	2.92	1.53	1.86	0.18	0.1	0.54	Poveda *et al.* (2019)
Mealworm	–	–	–	38.8	2.67	1.44	1.97	0.17	0.09	0.52	Poveda *et al.* (2019)
Mealworm larvae	–	–	–	42.44	7.75	1.02	1.15	0.28	0.11	0.34	Poveda *et al.* (2019)
Black soldier fly	5.5	44	–	42.9	4.54	1.23	2.44	0.49	0.64	0.13	Temple *et al.* (2013)
Black soldier fly	–	–	–	31.1	1.27	0.46	2.79	–	–	–	Rosmiati *et al.* (2017)
Black soldier fly	8.84	8.5	51.4	35.2	4.4	5.2	4.1	–	4.5	0.8	Setti *et al.* (2019)
Housefly	7.78	–	18.55	3.36	4.66	2.7	1.3	–	–	10.55	Zhu *et al.* (2015)
Housefly	8.5	–	29.8	78.23	3.2	2		–	–	0	Yang *et al.* (2015a)
Traditional compost	7.3	11	–	40.7	2.8	1.81	2.24	0.65	3.69	0.66	Temple *et al.* (2013)
Untreated manure	6.59	–	72.42	84.8	6.23	3.72	2.4	–	–	10.55	Zhu *et al.* (2015)
Peat	6.1	1.3			0.15						Setti *et al.* (2019)

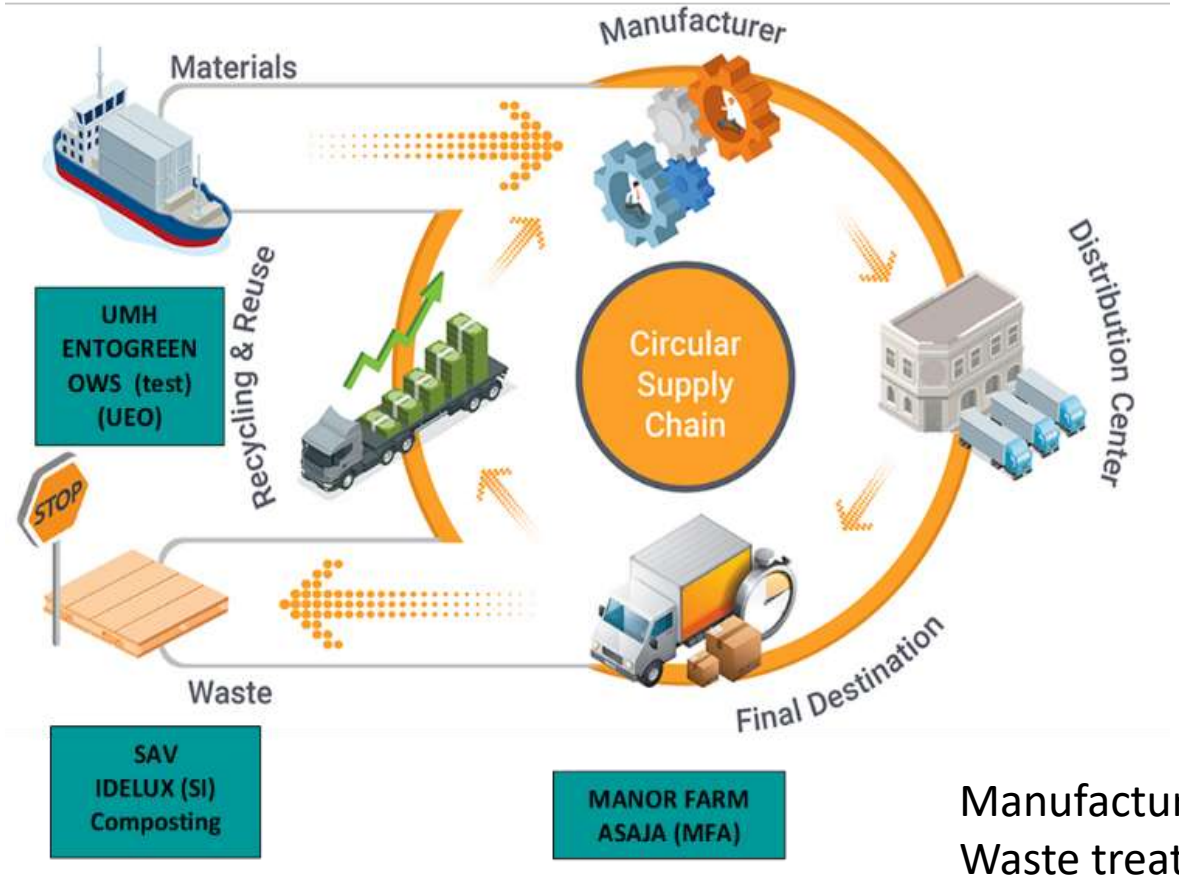
Chavez and Uchanski, M. (2021). J. Insects Food Feed, 1-12.

Value: Vermicompost



Poveda, J. (2021). Agron. Sust. Develop., 41(1), 1-10.

Logistic approach for RECOVER large scale implementation



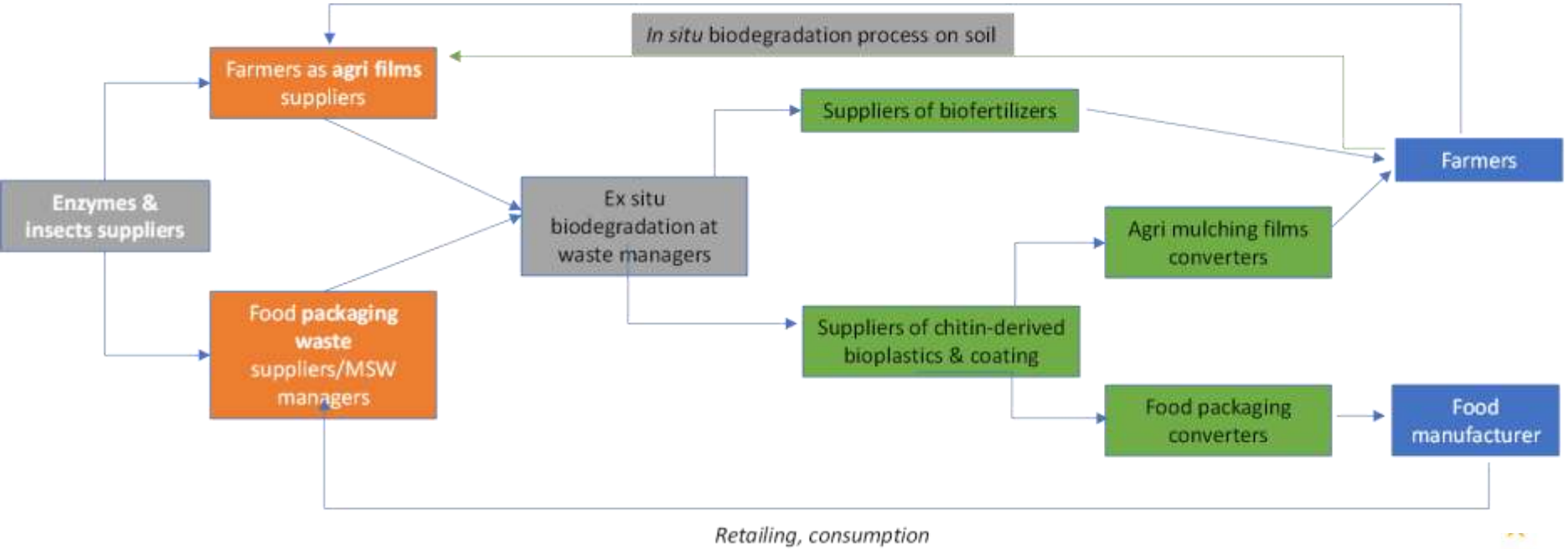
For the setting of an efficient and reliable logistic system for the new value chains, the consortium of the Recover Project created an only-line survey **(https://survey.tages.it/recover/)**

https://recover-bbi.eu/

Manufacturer
Waste treatment Company
Distribution/Warehousing Company
Farm

Expected Impacts

- **Convert agri-food waste plastics into chitin/chitosan-based plastics and new fertilizers** for the primary sector and bio-based food industries.
- Establish **a new circular cross-sectoral interconnection** in the biobased economy, involving **waste management and biotechnology**.
- Create **three new effective bio-based value chains** that **link standard plastics with insects/microorganisms and enzymes providers**.



Feedstock
Products
Application sectors
Technologies/processes

Expected Impacts

- **Reduce the generation and dispersion of microplastics and increase plastic recycling in EU by 12 %**
- Provide alternatives for the **removal of non-biodegradable plastics from the soil and the compost.**
- Contribute to **'close the loop' within the agricultural and packaging sectors** by converting AWP into biofertilizers and bioplastics for agriculture and packaging applications
- **Avoid around 80% of CO_2 emissions** caused by common incineration of plastic.

Thank you

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