AGRIMAX Training Webinar for End Users

Valorization of ferulic acid from wheat bran to obtain bio-based polymers for packaging applications

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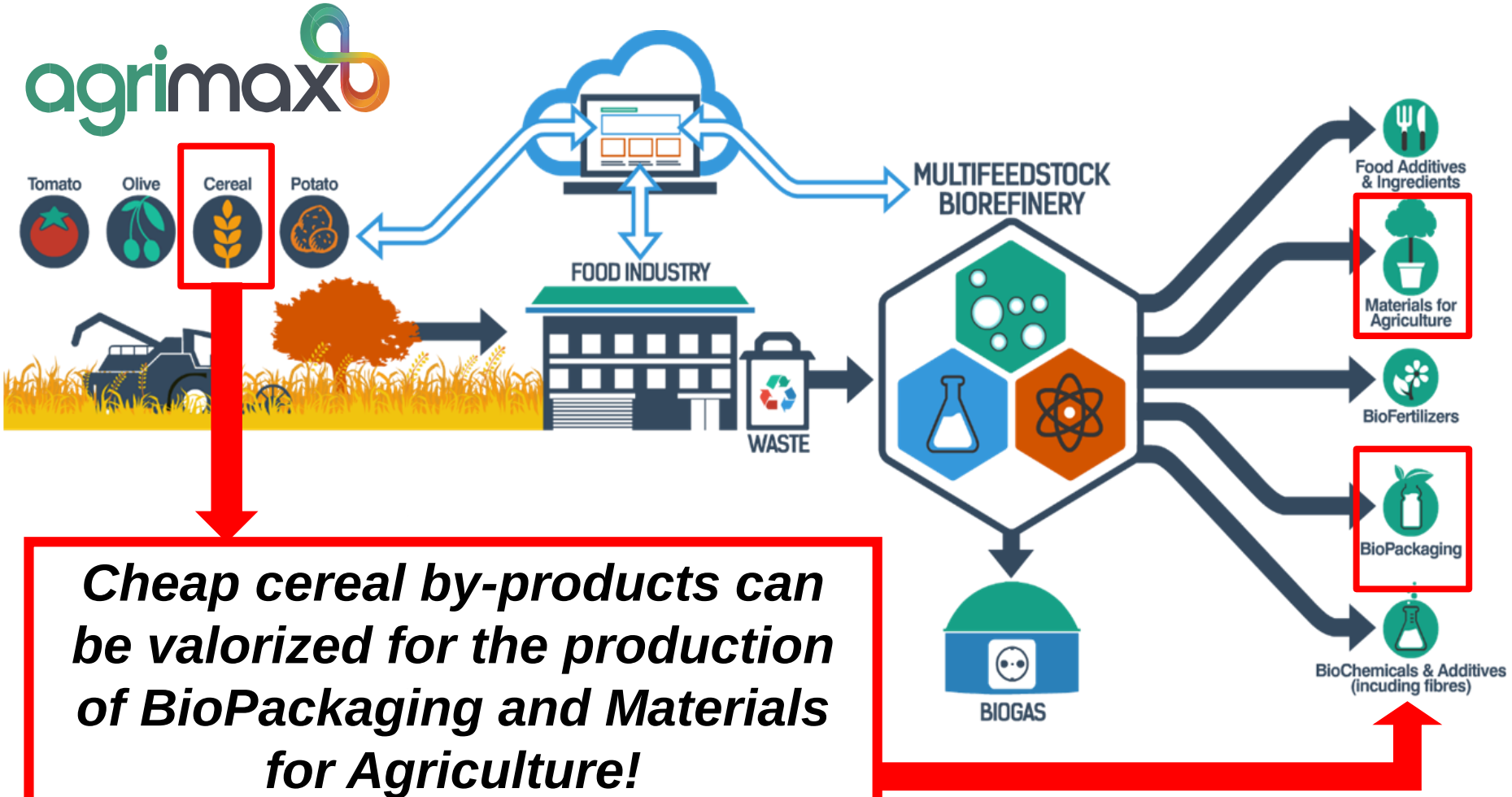
Bio-based Industries Consortium

This project has received funding from the Bio Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No. **720719**.

The Roadmap!



Cheap cereal by-products can be valorized for the production of BioPackaging and Materials for Agriculture!

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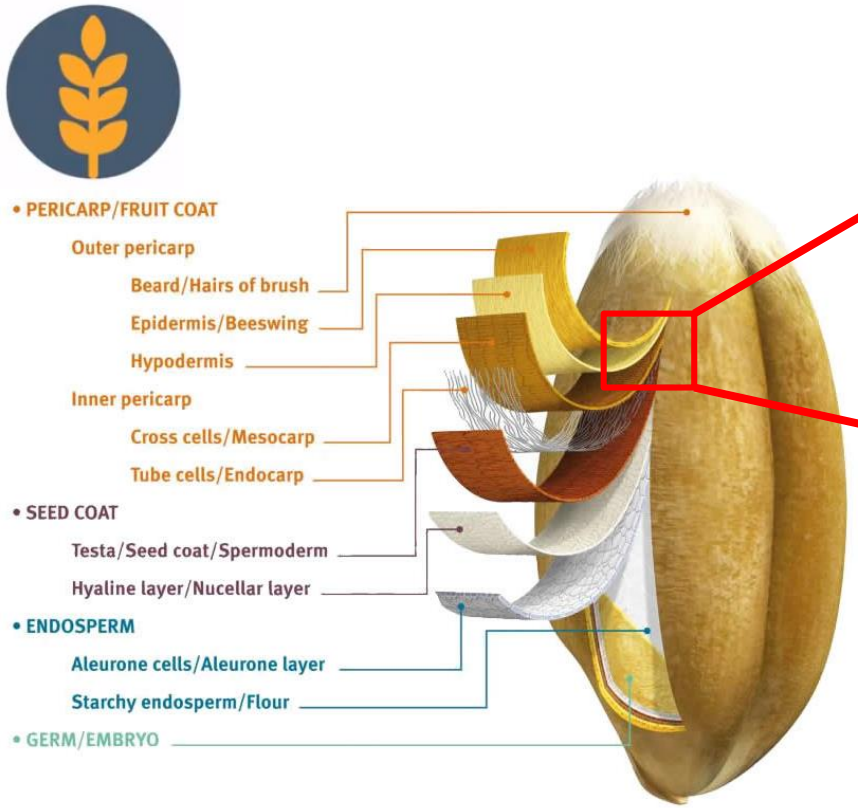
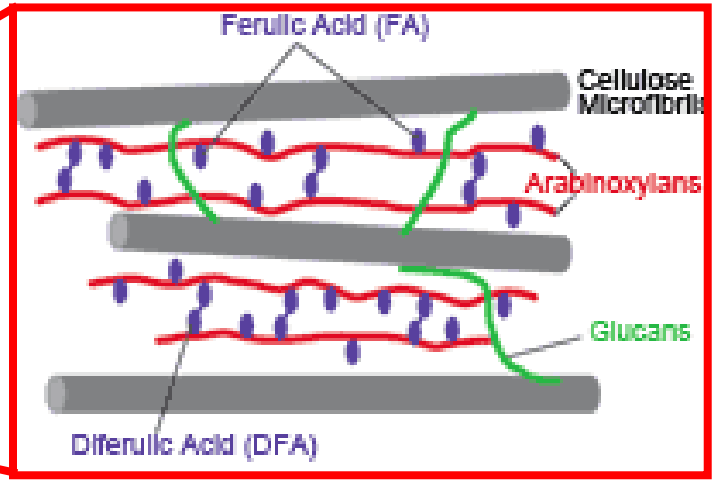
The Wheat Grain





Sugars, Peptides, Aminoacids, Fibers, Polyphenols, Ferulic acid

Wheat grain has a multi-layered structure: sequential milling led to different bran fractions

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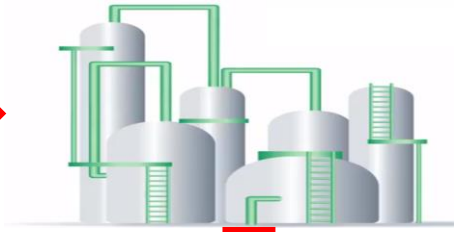
Wheat Bran



"total" bran

Barilla SpA – Durum wheat by-product production (Italy)			
YEAR	2018	2019	2020
Middlings (kt)	103	108	106
Bran (kt)	71	80	86

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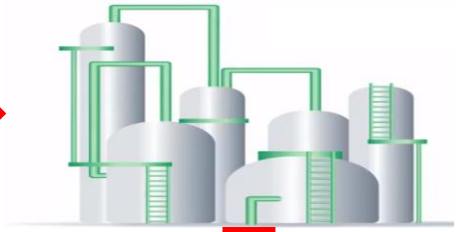
Wheat Bran



outer → inner

"total" bran

	Humidity (% w/w)	Ash (% w/w)	Proteins (% w/w)	Fibers (% w/w)	Lipids (% w/w)	Starch (% w/w)
Bran 1	14.8	6.9	12.1	66.9	5	9.1
Bran2	14.7	7.2	15.6	55.1	7	15.1
Bran 3	13.6	6.4	18.8	42.7	8	24.2
Farinaccio	12.9	4.3	17.6	30.8	5	42.2
Tritello	13.9	5.3	16.3	50.3	5	23.1

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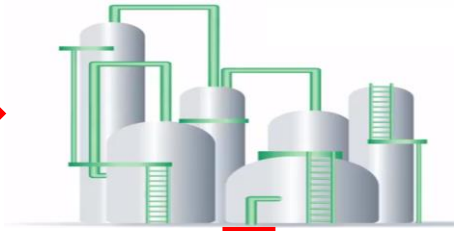
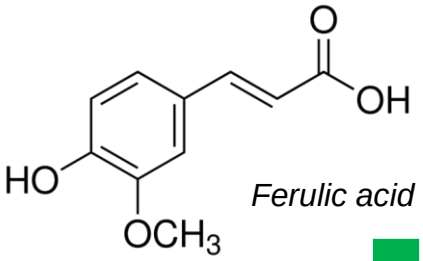
The strategy!



Direct exploitation

Extraction process



Ferulic acid

Mycelium-based materials

agrimax

Fully biobased
Secondary packaging

Additives for bioplastics
Monomers for Biopolymers

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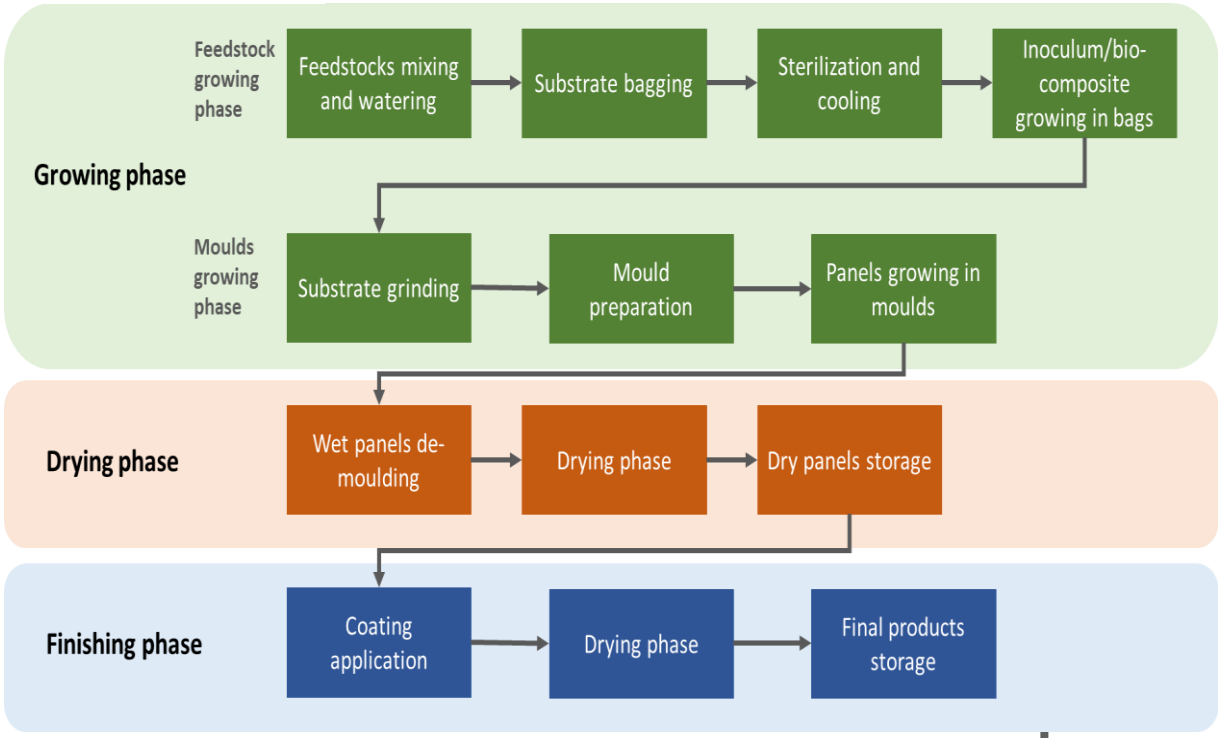
Bran and Mycelium-based materials

Developed by MOGU

Mycelium/Cotton/Bran

Mycelium/Hemp/Bran



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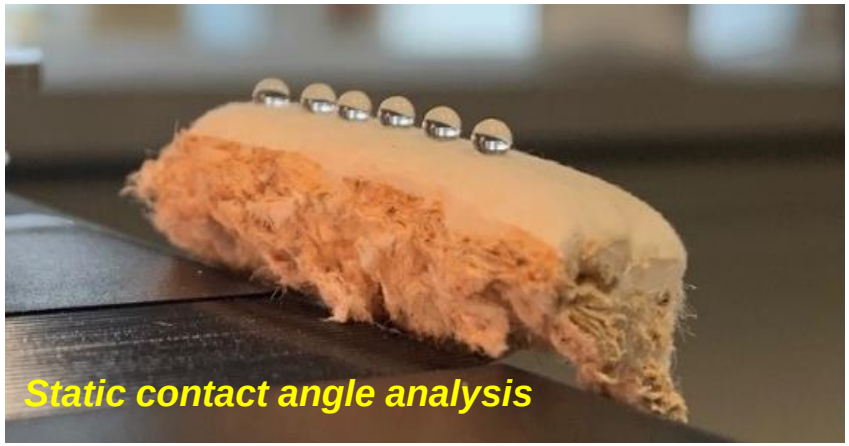
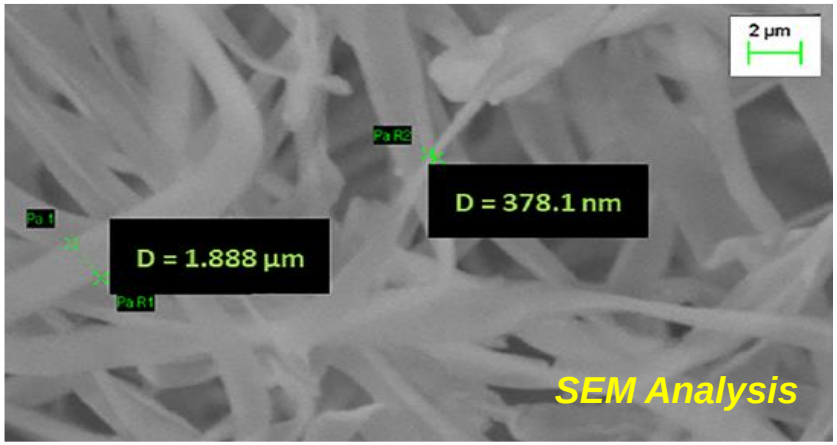
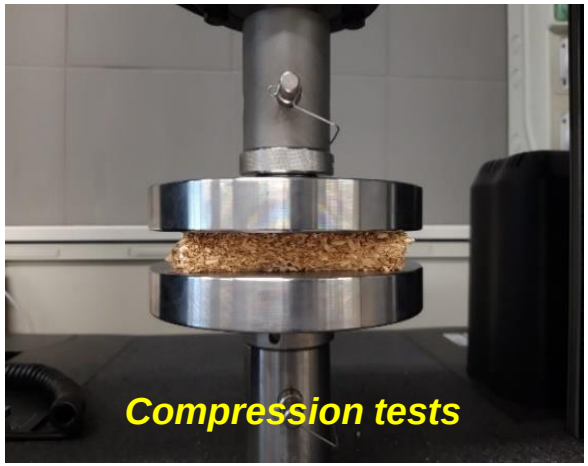
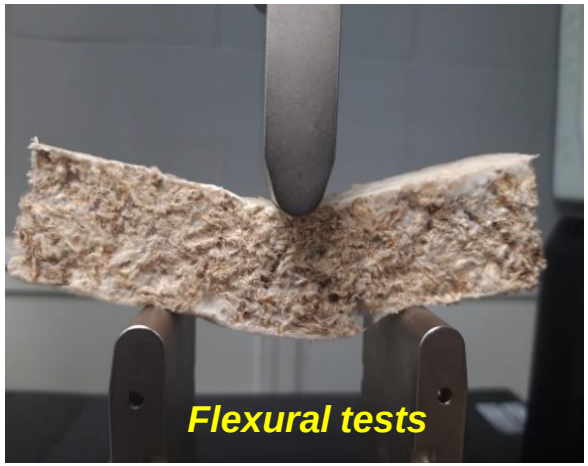
Bran and Mycelium-based materials







- *Wheat bran is beneficial to the mycelium growth, and to the mechanical properties (10-20%).*
- *The resulting materials are 100% natural and home-compostable*



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The extraction process

Department of Biological, Geological, and Environmental Sciences, University of Bologna, Italy.

1) Re-hydration (1:40) (thermal/pressure pre-treatment)

2) Extraction technology: enzymatic treatment vs alkaine hydrolysis

Insoluble fibers

Digestate

3) Solid phase adsorption

Sugar and Peptides

Ferulic acid

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The extraction process

Scale-up of the process…

Pilot scale @ CHIESA: 25Kg
Assessment and optimization of the reaction condition in industrially relevant environment

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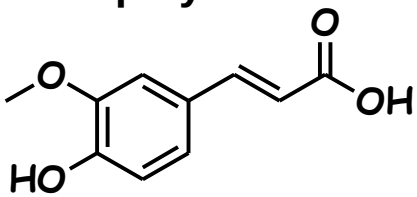
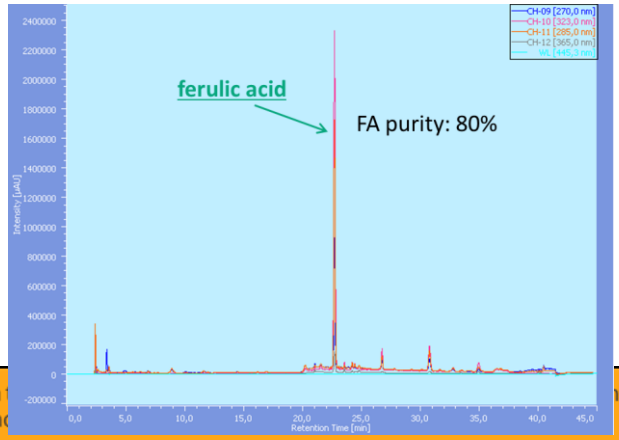
The extraction process

Scale-up of the process…

Monitoring the composition of the extracts at each step by HPLC analysis!





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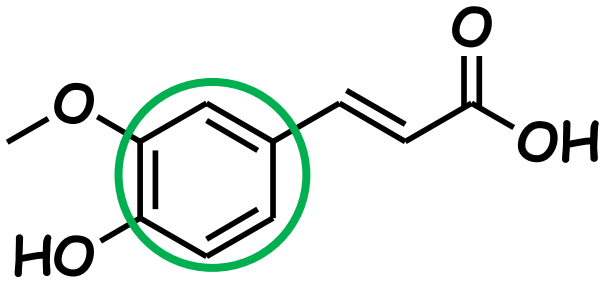
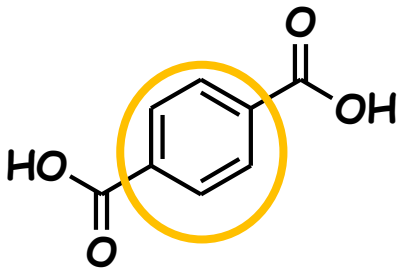
Why Ferulic acid?

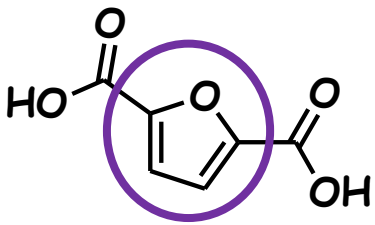


- Biobased
- Derived from waste
- NO competition with food
- May confer additional properties to the materials
- Harmless



Terephthalic acid

- Main component of PET
- NO biodegradation
- Derived from petrol



Furanedicarboxylic acid

- Best candidate to substitute terephthalic acid
- From carbohydrates (in competition with food)
- Confers high barrier properties

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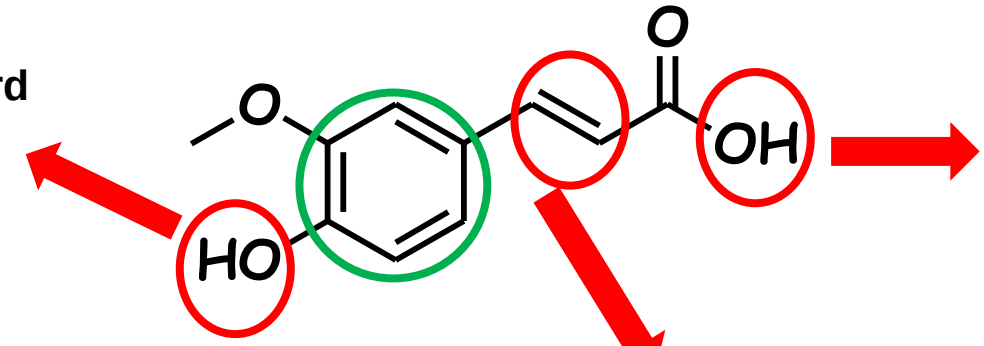
The chemistry of Ferulic acid

Phenol:
Poor reactivity toward polycondensation
BUT
Great antioxidant effect

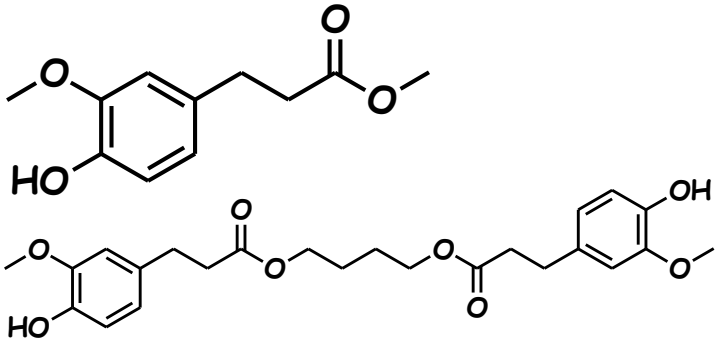


Carboxylic acid:
Possible promoter of degradation

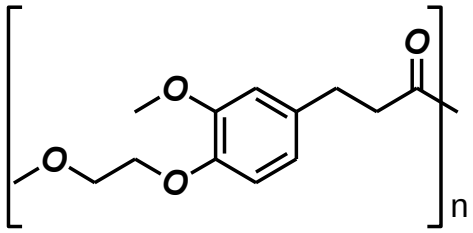
Double bond:
Sources of degradation

Chemical modification!

Additives for plastics



Polymers



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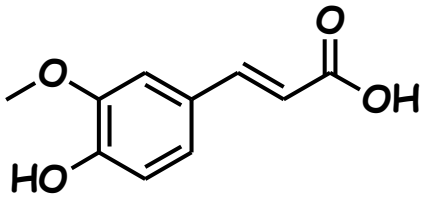
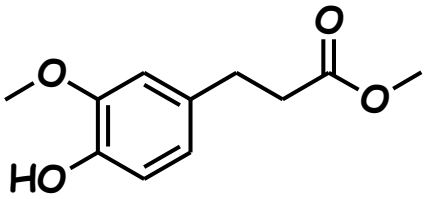
Additives from ferulic acid



Ferulic Acid

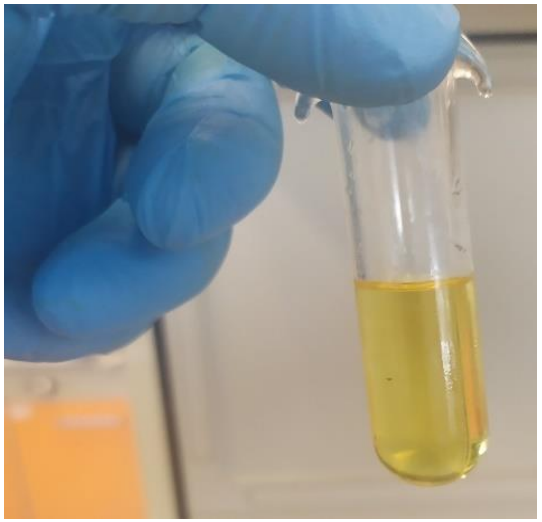
H_2

Pd/C; MeOH; 50°C



Methyl dihydro ferulate

- **Mild conditions**
- **Recyclable catalyst**
- **One pot**



Lab scale 600g

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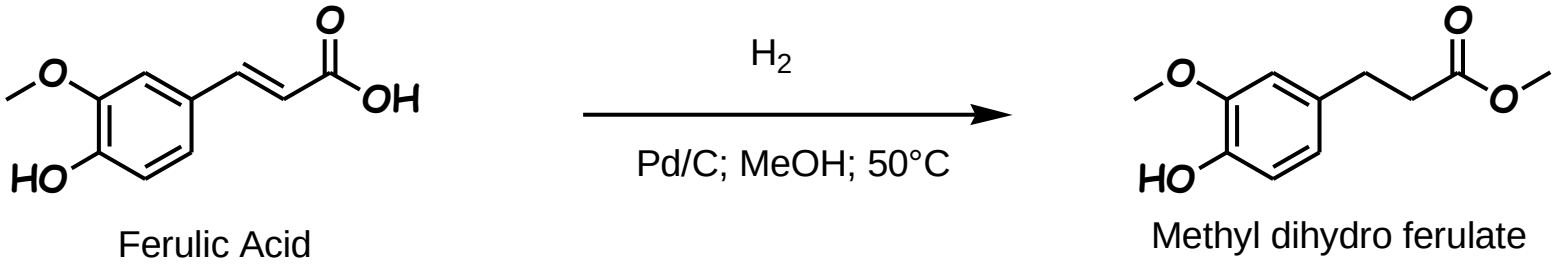
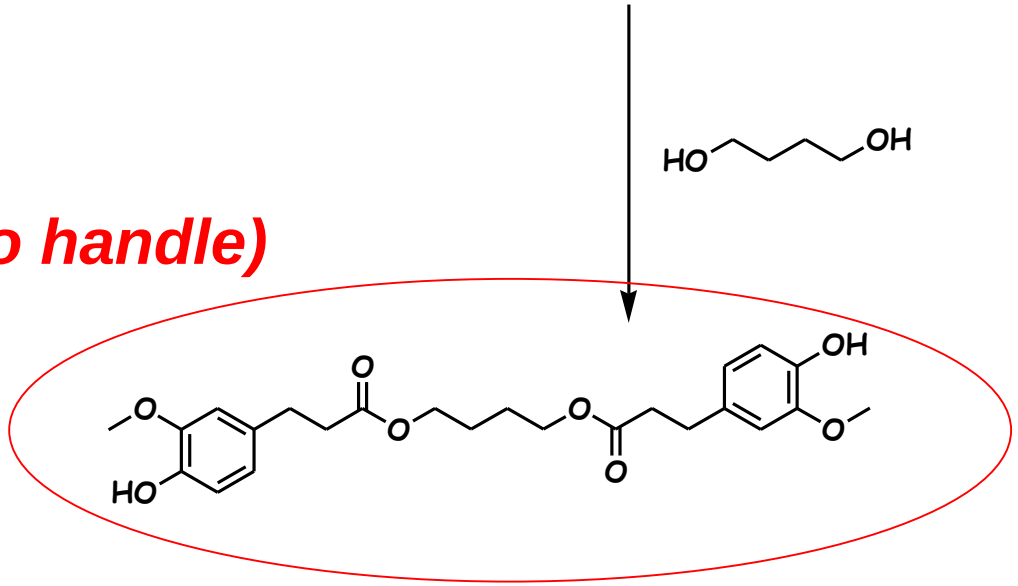
Additives from ferulic acid



Ferulic Acid

Methyl dihydro ferulate



Soild additive (easier to handle)

100% Biobased

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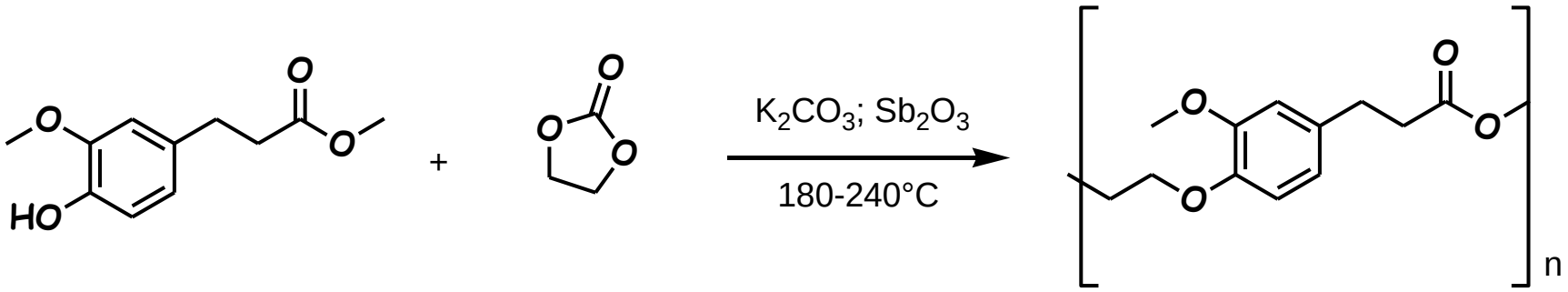
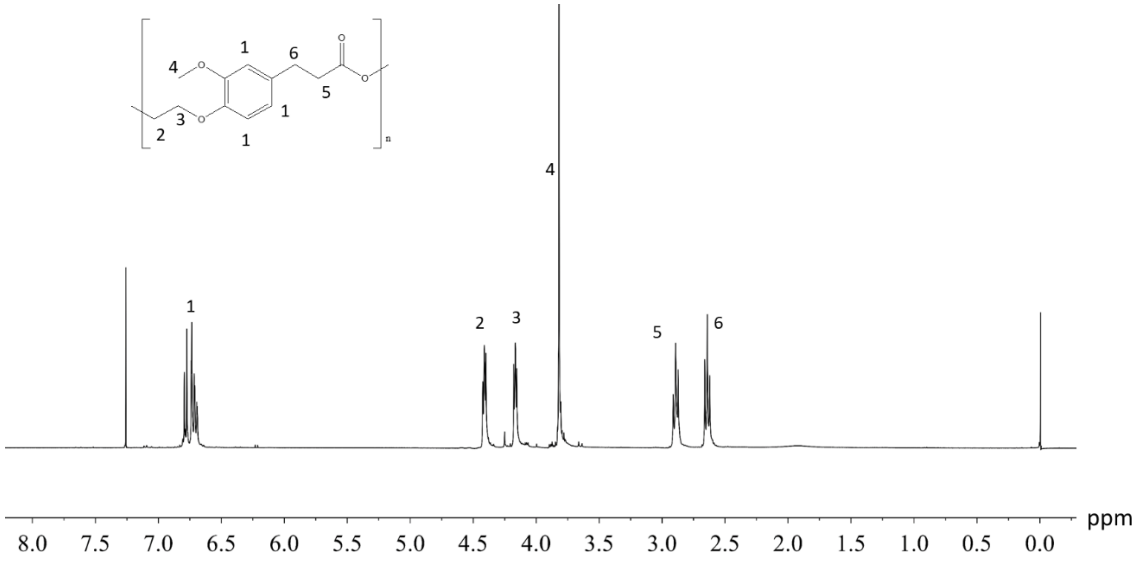
Polymer from Ferulic Acid



Poly-dihydro (ethylene ferulate)
PHEF

Structure analysis: NMR Characterization



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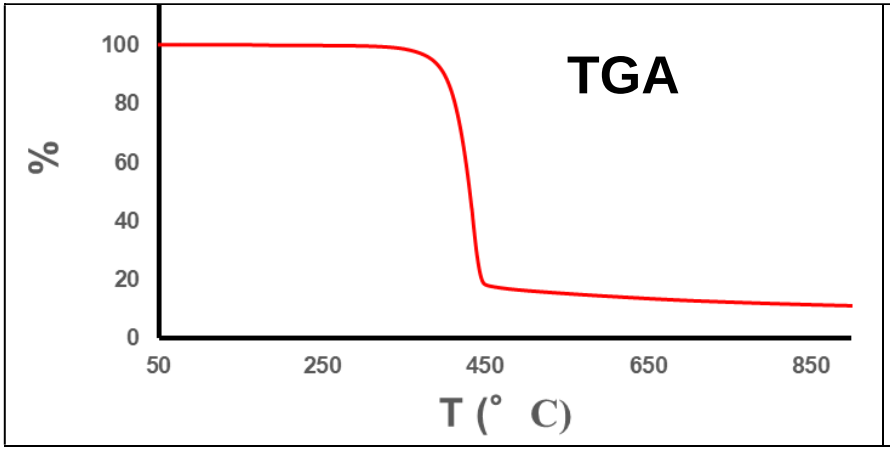
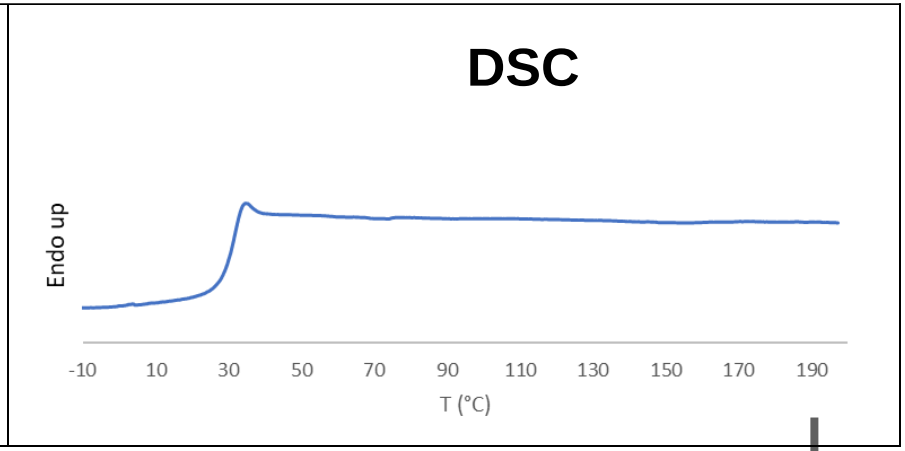
Polymer from Ferulic Acid

TGA		DSC	GPC	
T_{onset} (° C)	T_{max} (° C)	Tg (° C)	Mw (Da)	PDI
398	435	30.4	33000	2.9

Thermal analysis





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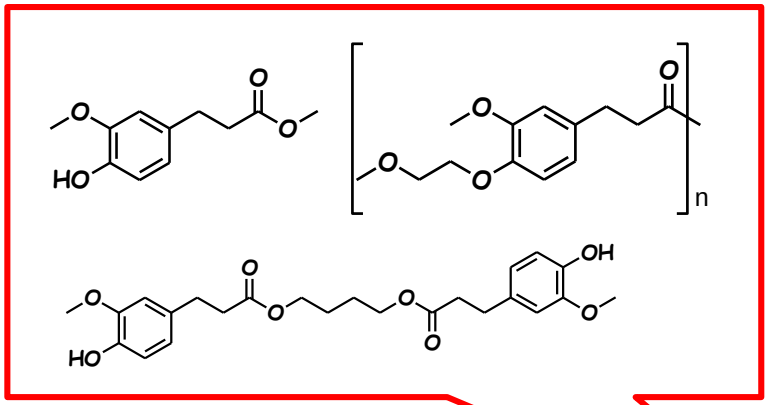
Formulations and Blends



Ferulic acid derivatives

PLA **PBAT**

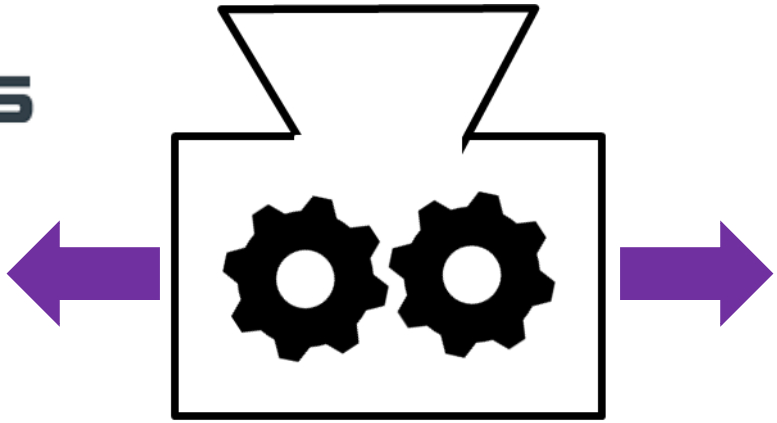
PHBV **PBSA**

ECOVIO

Commercial Biopolymers

AIMPLAS
PLASTICS TECHNOLOGY CENTRE

Materials for agriculture



Extrusion

CENTRO TECNOLÓGICO ITENE

Active Bio packaging

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Conclusions

Take-home massages!

1) **Wheat bran can be converted from by-product to source of useful compounds.**

2) **Different strategies can be devised (direct incorporation in mycelium materials or refined to obtain building blocks)**

3) **Ferulic acid can be successfully modified into antioxidant additives or even polymers by means of integrated, sustainable strategies**

4) **Ferulic derivatives can be exploited to make formulation or blends with biopolymers**

Thank you for your kind attention!

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