



Innovative bioplastics from polypeptides of *Hermetia illucens*

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ISCaMaP

Innovative Sustainable Chemistry and Materials and Proteins Group



Politecnico di Milano, Department of Chemistry, Materials and Chemical Engineering “G. Natta”

Waste & resource Management

Organic Fraction of Municipal solid waste (**OFMSW**) MANAGEMENT



Europe (2021):
More than **200 million tons** of MSW

OFMSW: **30-70%** of MSW

Over-abundance of plastic products



6.3 billion tons of plastics trash in the world

Less than **9%** of plastic is recycled

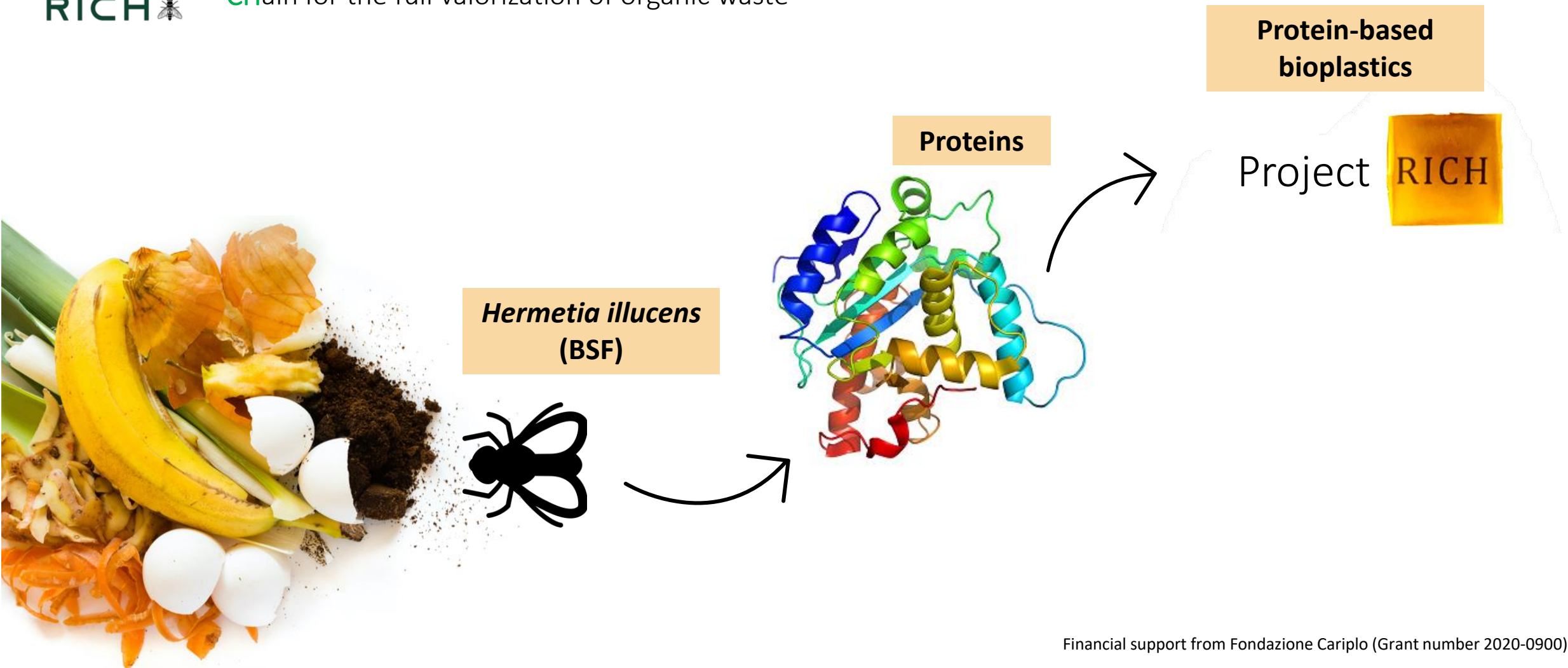
Land and water consumption for conventional **bioplastics**



6% of land is actually used for bioplastics and biofuels



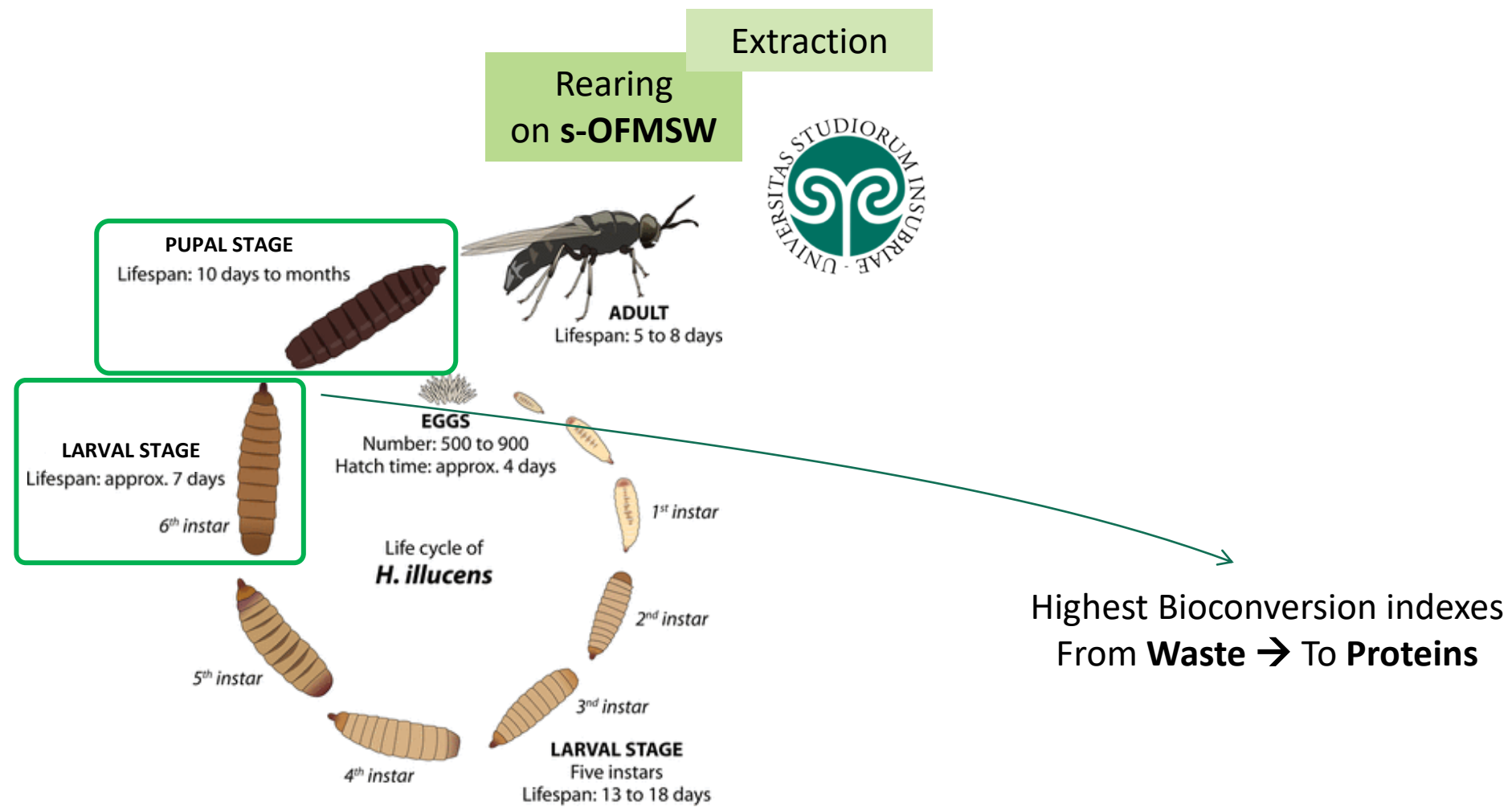
Turning **R**ubbish **I**nto biobased materials: a sustainable **CH**ain for the full valorization of organic waste



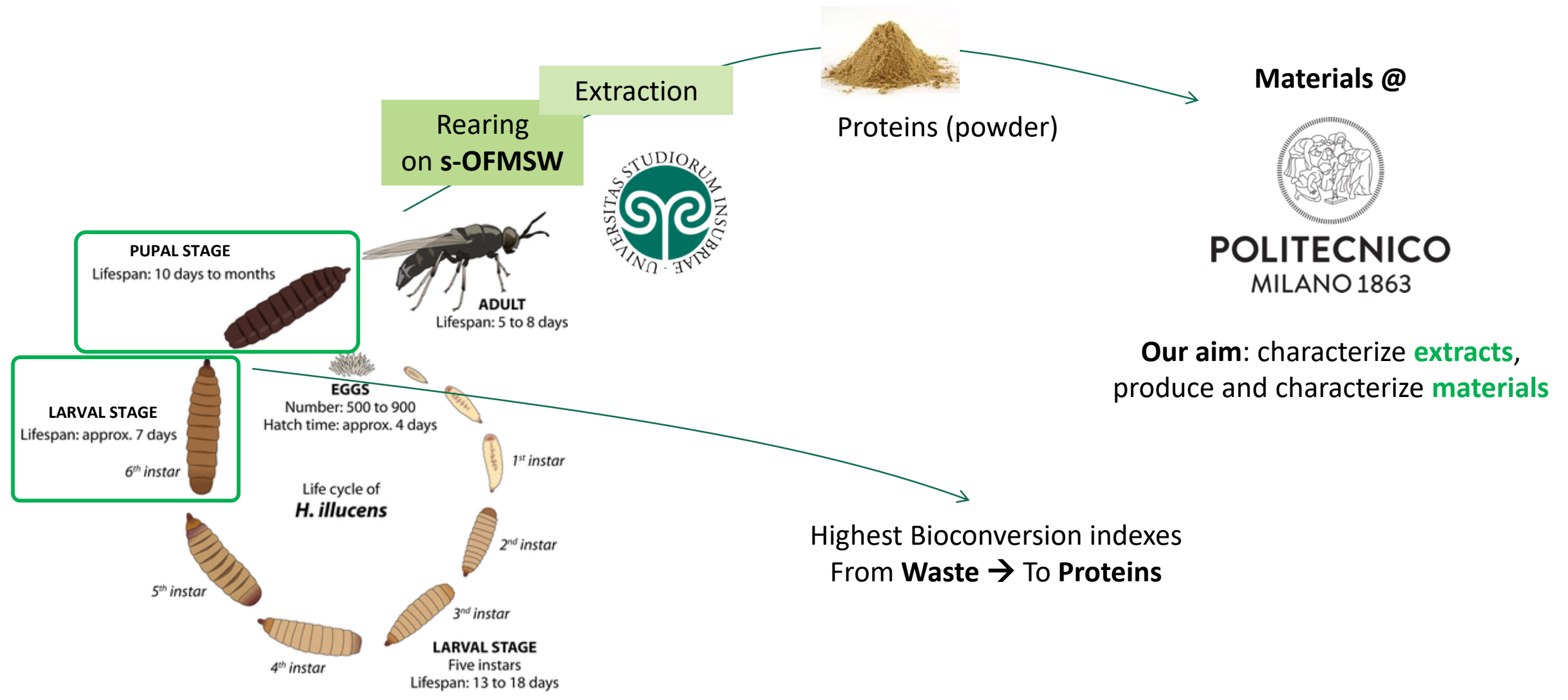
Financial support from Fondazione Cariplo (Grant number 2020-0900)



From Larvae and Pupae to proteins



From Larvae and Pupae to proteins





Extracts characterization

What do we have inside extracts?

How much proteins do we have?



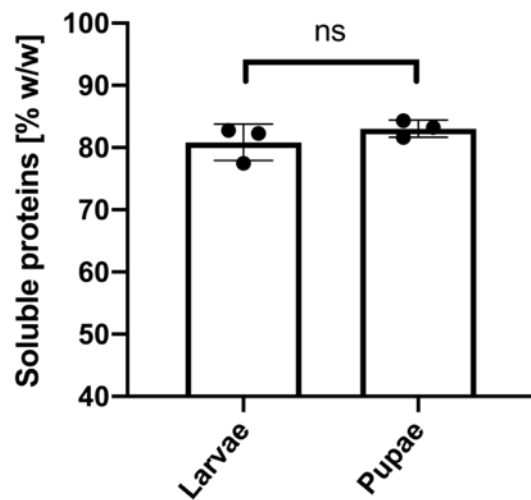
Extracts were solubilized at **pH 10, 80°C**

BCA

UV-Vis
Spectroscopy

SDS-PAGE

Nano LC-MS



~80% of proteins
Same amount of proteins in extracts

	Larvae	Pupae
Mean [%]	80,84	83,05
SD [%]	2,93	1,36

[Pierce™ BCA Protein Assay Kit, Catalog Numbers 23225 and 23227]

What about solubility and stability?



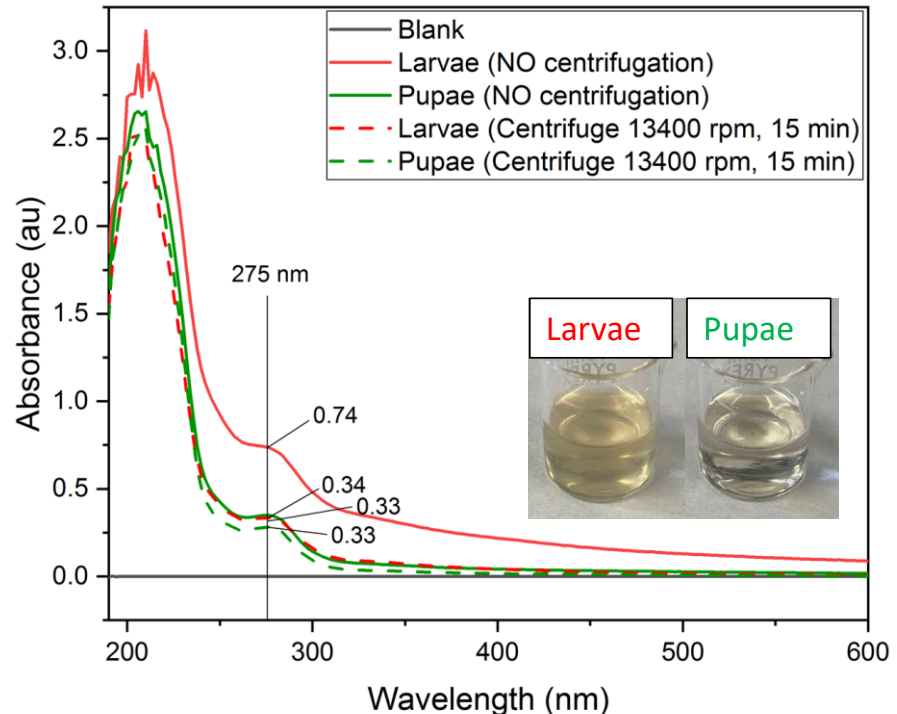
Extracts were solubilized at **pH 10, 80°C**

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UV-Vis Spectroscopy

SDS-PAGE

Nano LC-MS



Heavier or insoluble compounds
in Larvae extract

Which are the protein weights?



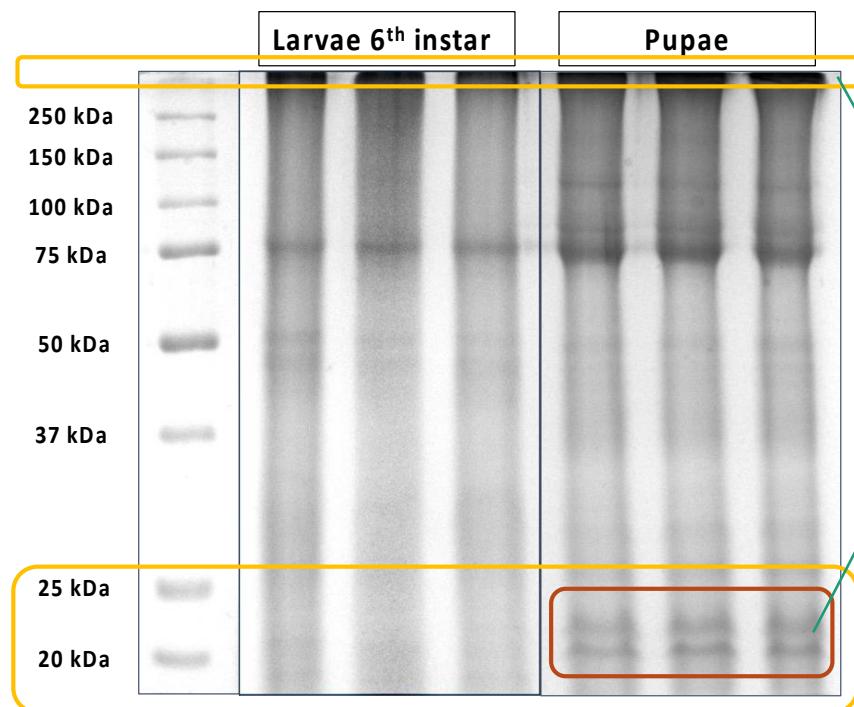
Extracts were solubilized at **pH 10, 80°C**

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Nano LC-MS



- Very **high MW** in Larvae extracts
- Pool of **lower MW** in Pupae extract

C. D'Ambrosio *et al.* Exploring the chicken egg white proteome with combinatorial peptide ligand libraries
J Proteome Res, 7 (2008), pp. 3461-3474

Which proteins are inside?



Extracts were solubilized at **pH 10, 80°C**

BCA

UV-Vis
Spectroscopy

SDS-PAGE

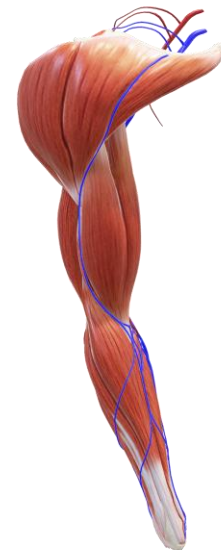
Nano LC-MS

- Myosin heavy chain, muscle
- Actin-87
- L-lactate dehydrogenase
- Tropomyosin-2
- Tropomyosin-1
- Tropomyosin Lep
- Muscle-specific protein 20

Prevalence of **MUSCULAR PROTEINS**

Requirements :

- **Mechanical strength**
- **Elasticity**

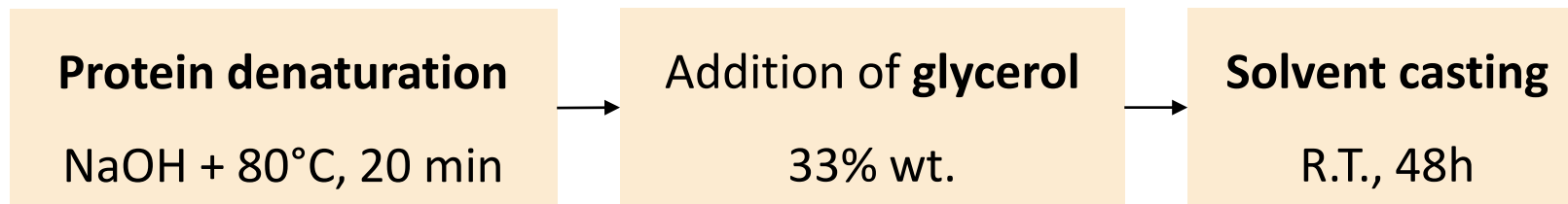




Film production & materials characterization

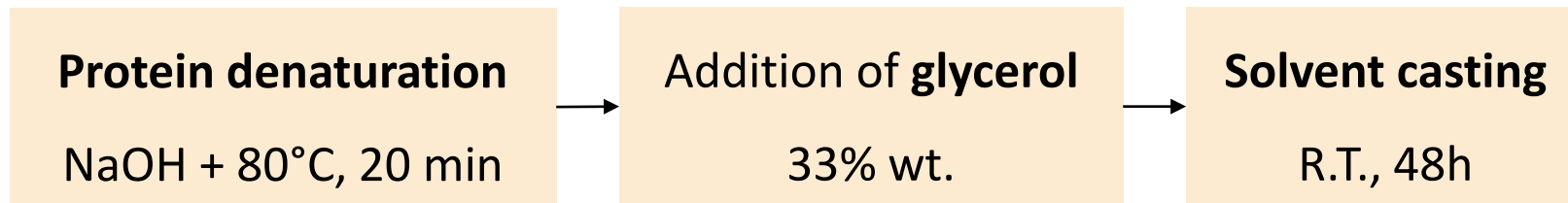
What about the polymeric network and structures?

How we made it...



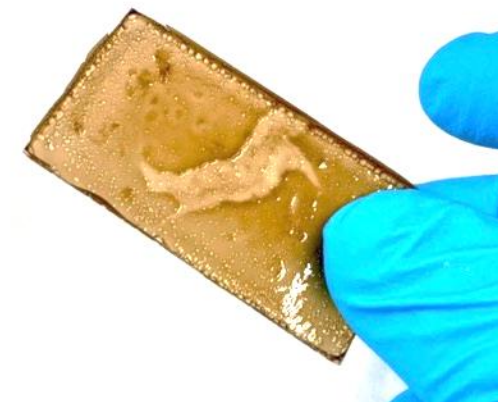
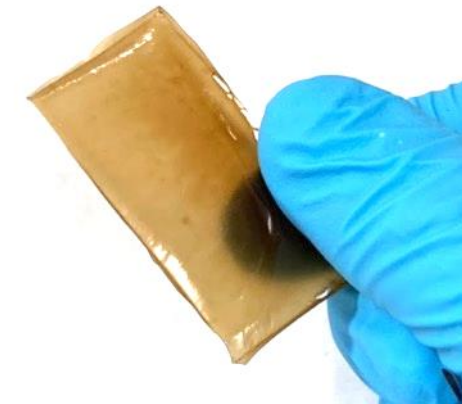
✗ Centrifugation → No material discarded

How we made it...



✗ Centrifugation → No material discarded

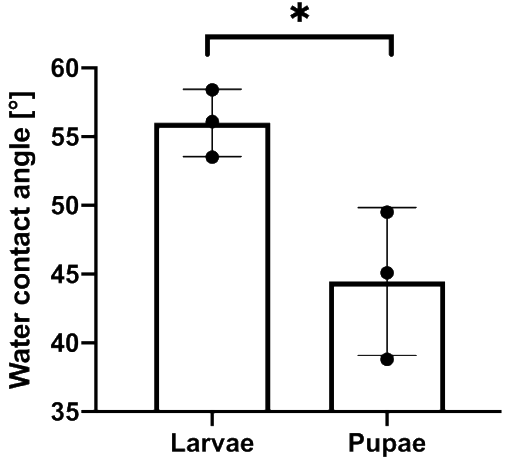
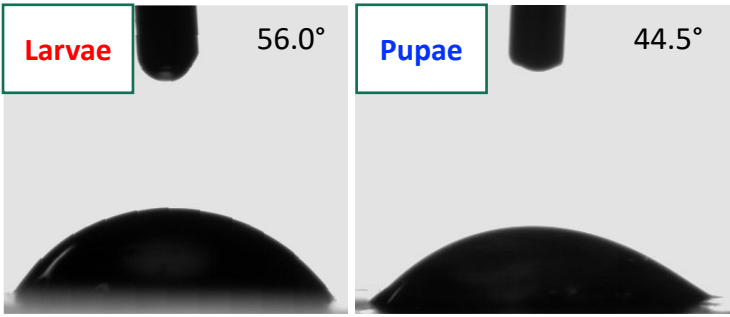
Larvae 6° instar



Pupae

[S. Barbi, M. Messori, T. Manfredini, M. Pini, and M. Montorsi, Rational Design and Characterization of Bioplastics from *Hermetia Illucens* Prepupae Proteins, *Biopolymers*, no. November **2018**, DOI: 10.1002/bip.23250]

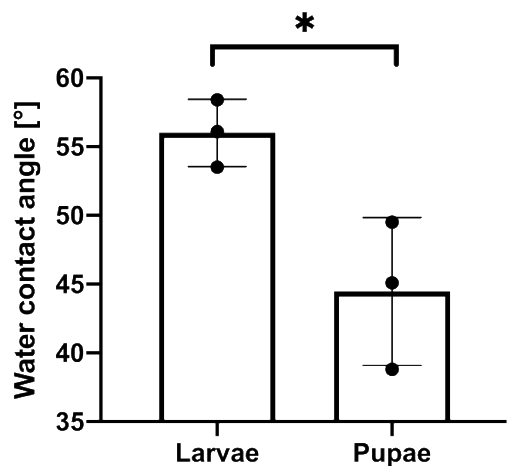
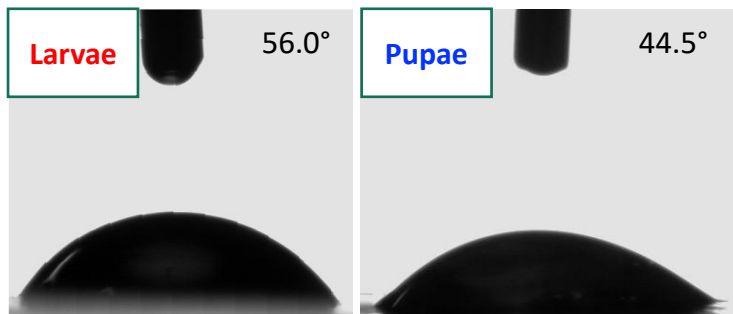
Water uptake of the films: Contact angle



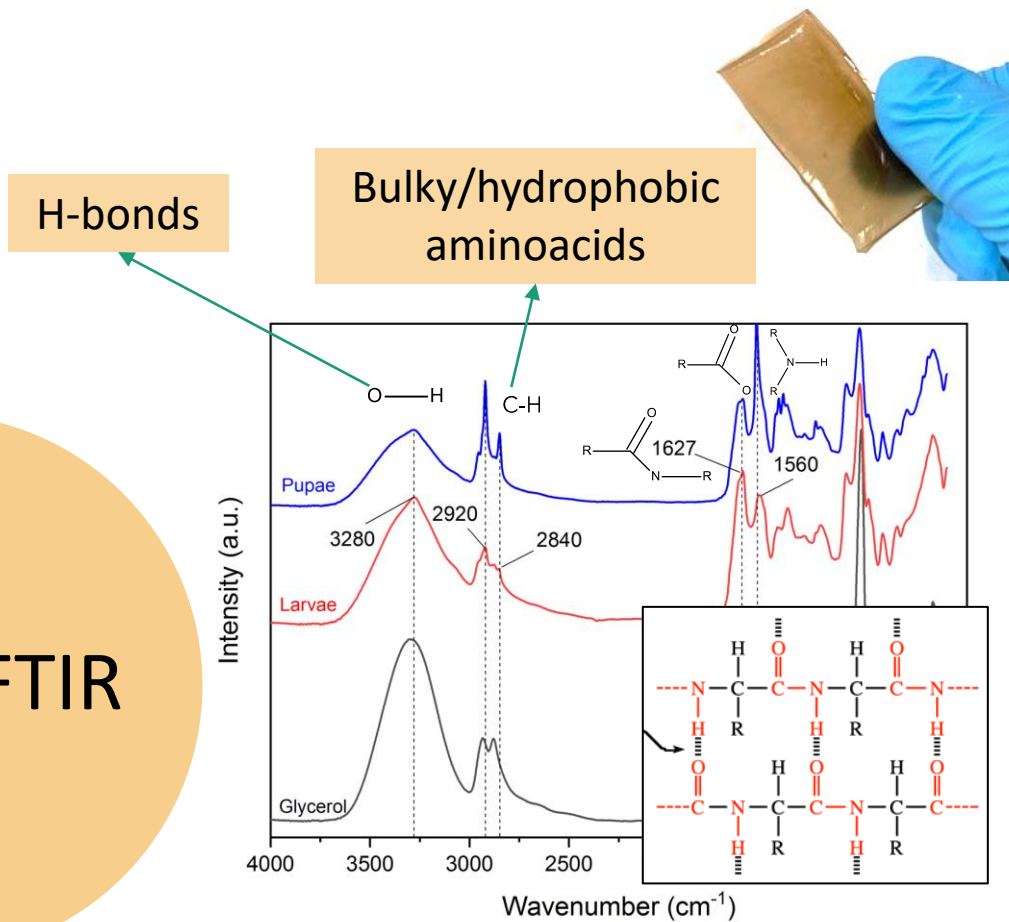
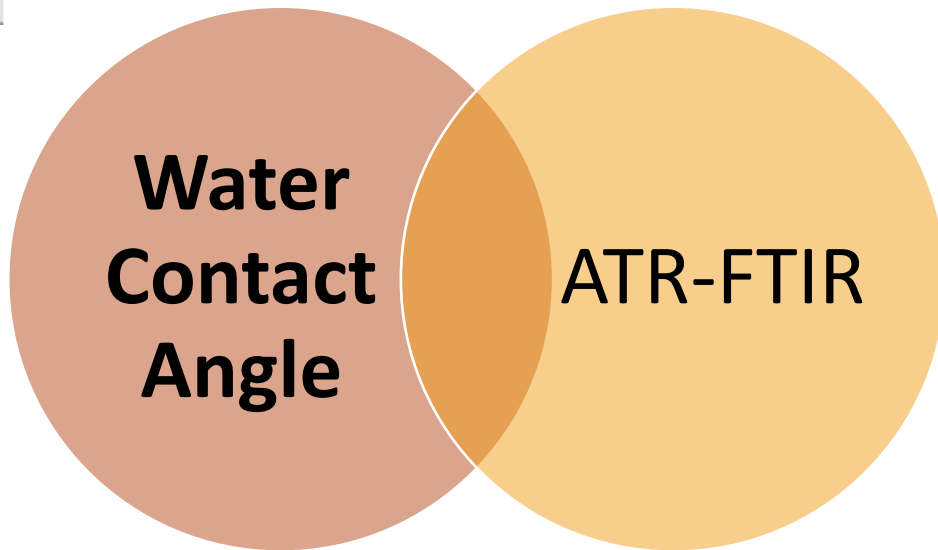
Water Contact Angle

Lower water uptake in films from larvae extracts -> **finer network mesh**

Chemistry of the films: ATR-FTIR



Lower water uptake in films from larvae extracts -> **finer network mesh**



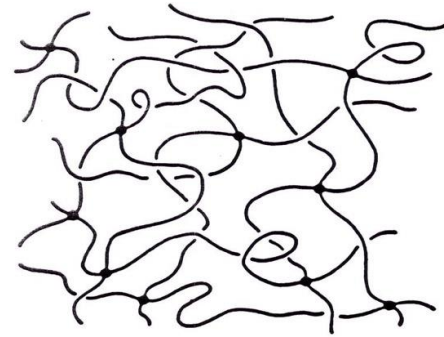
More supramolecular interactions in films from larvae extracts

Conclusions

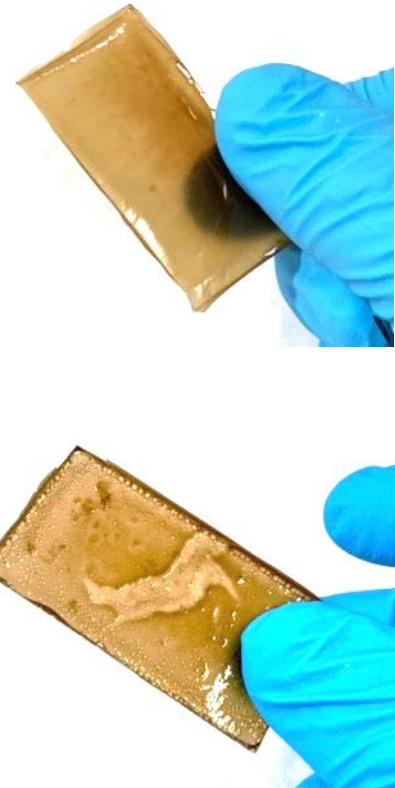
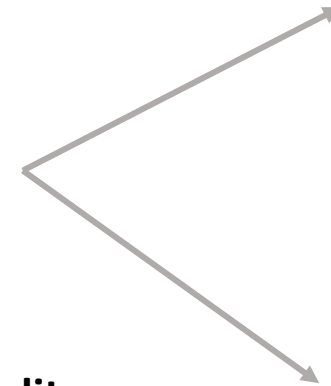
- ✓ **Protein extracts** were characterized
- ✓ **Bioplastics** were produced and characterized
- ✓ The **optimal life stage** was selected

Key points:

- **Self-assembling** ability (polar groups)
- **Low Molecular weights** (MW)
- **Hydrophobic/bulky** AA residuals



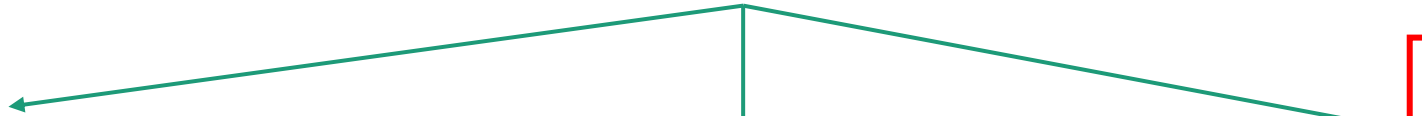
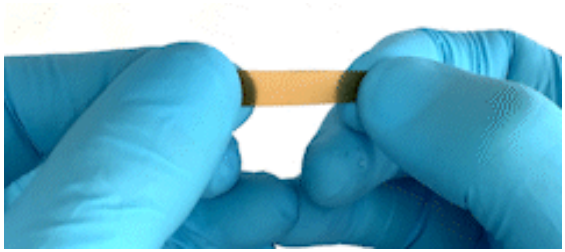
Entanglements & network quality



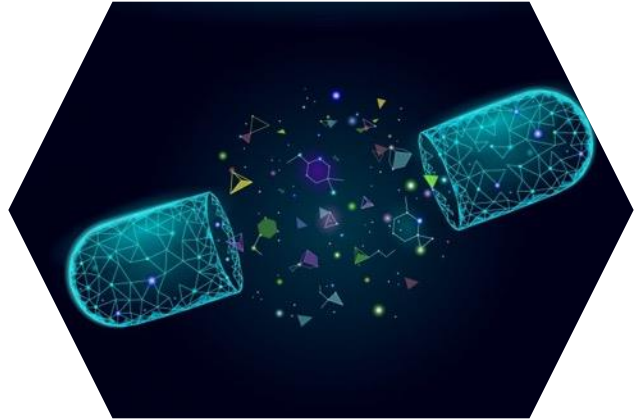
Future perspectives: some applications...

BSF protein film from Larvae at 6^o instar

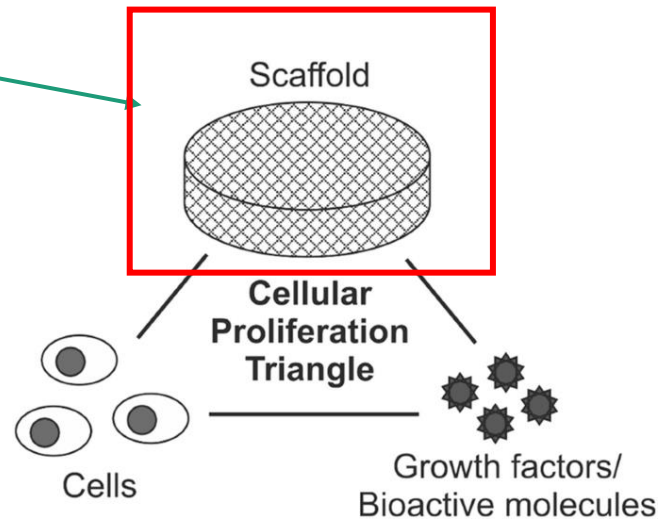
After immersion in H₂O



Edible packaging



Drug release



Tissue engineering

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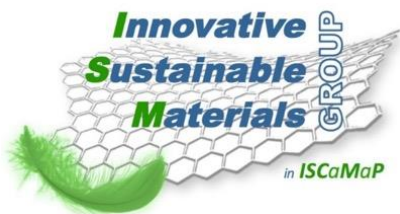
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Thanks
for your kind attention!

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