Biodegradation of polyethylene by macro-organisms such as mealworms and greater wax moth larvae: technological application potential

Pieter Billen, Sabrina Spatari, Serge Tavernier

University of Antwerp

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Correspondence

Polyethylene bio-degradation by caterpillars of the wax moth *Galleria mellonella*

Paolo Bombelli [1], Christopher J. Howe [1], Federica Bertocchini [2, 3]

The Guardian Tue 25 Apr 2017

Science & Environment

Plastic-eating caterpillar could munch waste, scientists say

By Helen Briggs
BBC News

24 April 2017 Share

Rups van de grote wasmot eet plastic (zakken) op

De rups van de grote wasmot, een soort nachtvlinder, blijkt plastic te eten en dat aan een hoog tempo. Daarmee is natuurlijk de gigantische plasticberg nog niet weggewerkt, maar het schept hoop en opent vooral perspectieven. Het diertje breekt onder meer polyethyleen af. En dat wordt vooral gebruikt om plastic winkeltassen te maken.

Sandra Cardoen
di 25 apr 2017 10:38

Plastic-etende rups ontdekt: hoopgevend, maar het plasticprobleem blijft

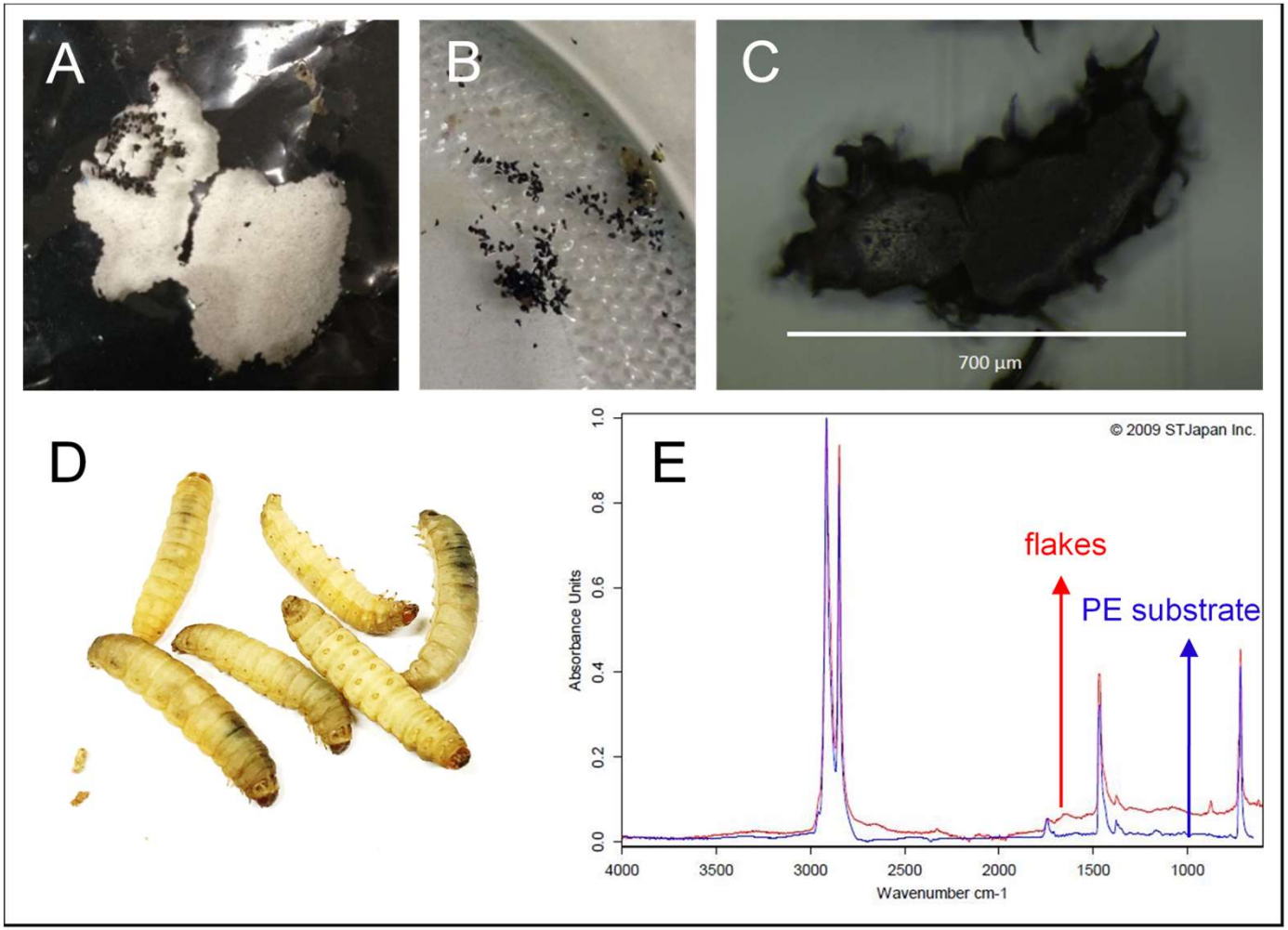
Plastic is een hardnekkig probleem. We produceren jaarlijks miljarden kilo's afval, maar een oplossing voor de vervuiling lijkt ver weg. Tot nu: wetenschappers stuitten toevallig op een rups die op relatief hoge snelheid plastic kan opeten én verteren. Gisteren verschenen de resultaten in het wetenschappelijke tijdschrift *Current Biology*.

Anne ter Rele 25-04-17, 18:54

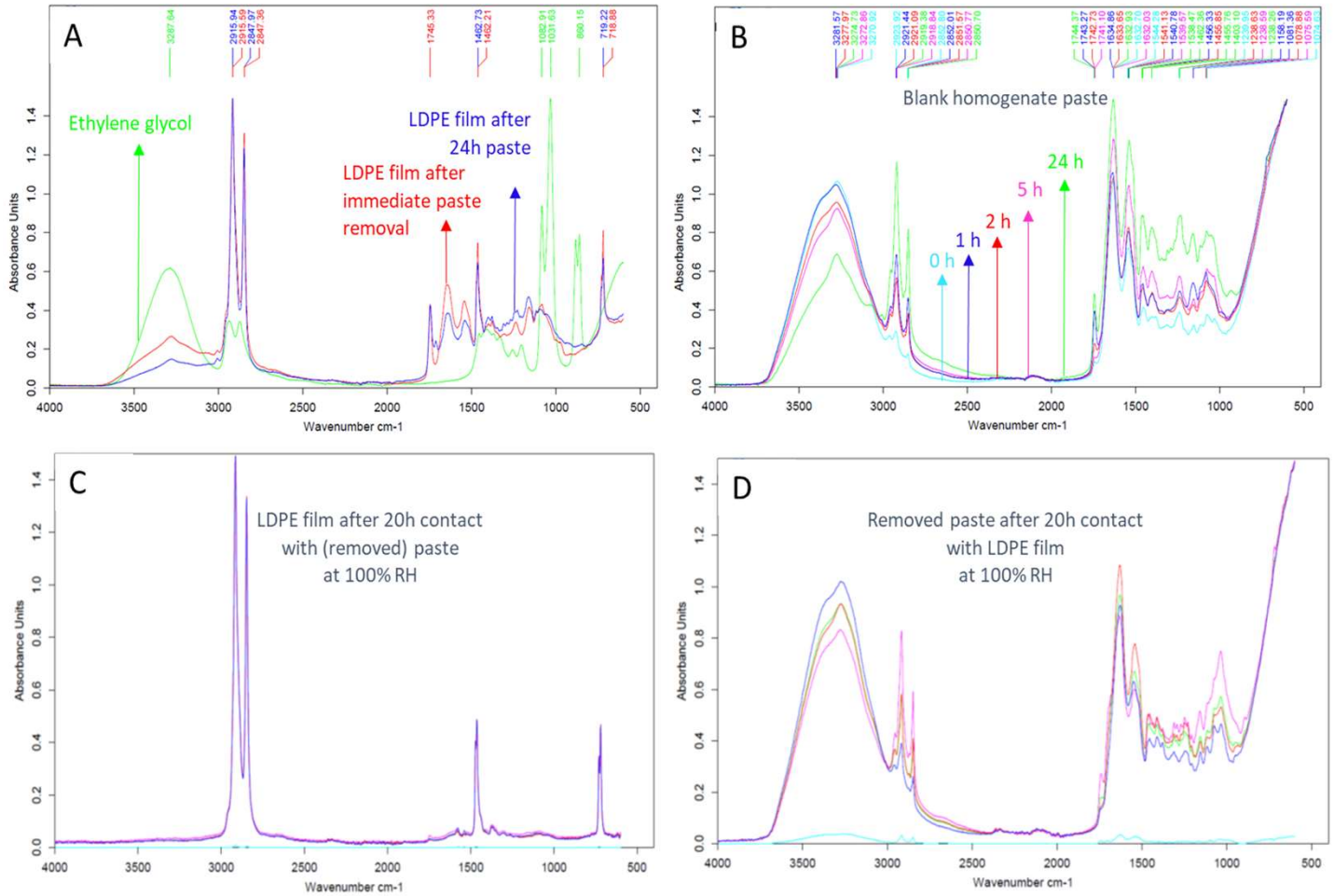
Experiments

Format	Species	Substrate	Time	Experiment code
Live larvae	Galleria mellonella	Loosely folded cling film (LDPE)	17 h	$live_{GWM}\_1$
		Loosely folded cling film (LDPE)	89 h	$live_{GWM}\_2$
		Folded layers cling film (LDPE)	96 h	$live_{GWM}\_3$
		Loosely folded black bag (LDPE)	216 h	$live_{GWM}\_4$
	Tenebrio molitor	Loosely folded cling film (LDPE)	38 days	$live_{MW}\_1$
		Commercial fruit bag (LDPE)	38 days	$live_{MW}\_2$
		None (blank)	38 days	$live_{MW}\_3$
		Bran	38 days	$live_{MW}\_4$
Homogenate	Galleria mellonella	Cling film (LDPE)	48 h	$paste_{GWM}\_1$
		Cling film (LDPE) at 100 % RH	20 h	$paste_{GWM}\_2$
		Cling film (LDPE) and blank paste	0 – 120 h	$paste_{GWM}\_3$
		Liquid paraffin at 100 % RH	14 days	$paste_{GWM}\_paraffin$
		Polystyrene (PS) powder at 100 % RH	14 days	$paste_{GWM}\_PS$
	Tenebrio molitor	Liquid paraffin at 100 % RH	14 days	$paste_{MW}\_paraffin$
		Polystyrene (PS) powder at 100 % RH	14 days	$paste_{MW}\_PS$

Live larvae with polyethylene



Degradation by biomass paste?

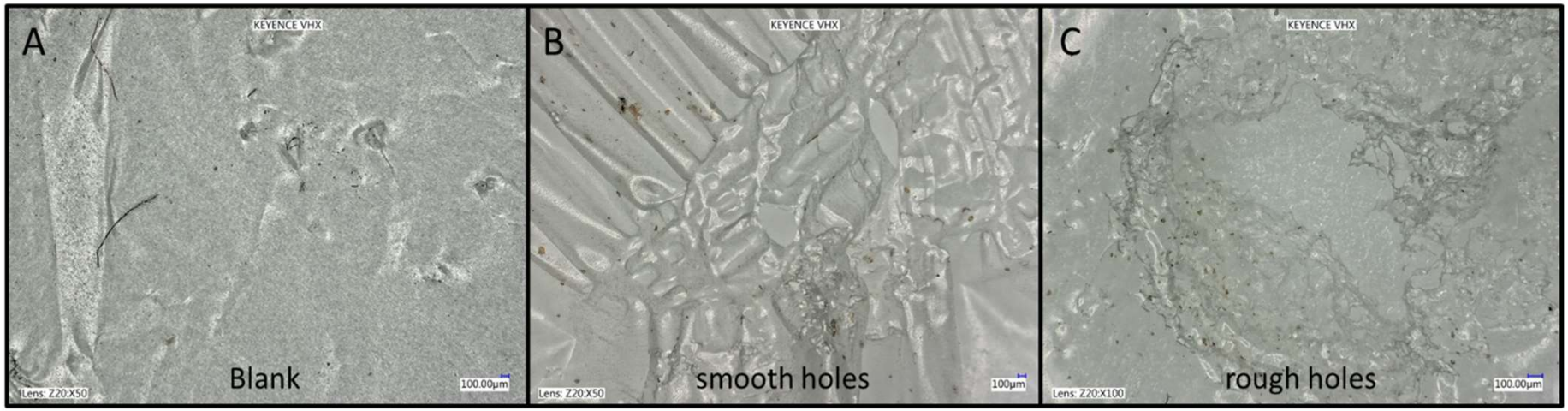


No gravimetric changes

No glycol (confirming *Weber et al.* 2017)

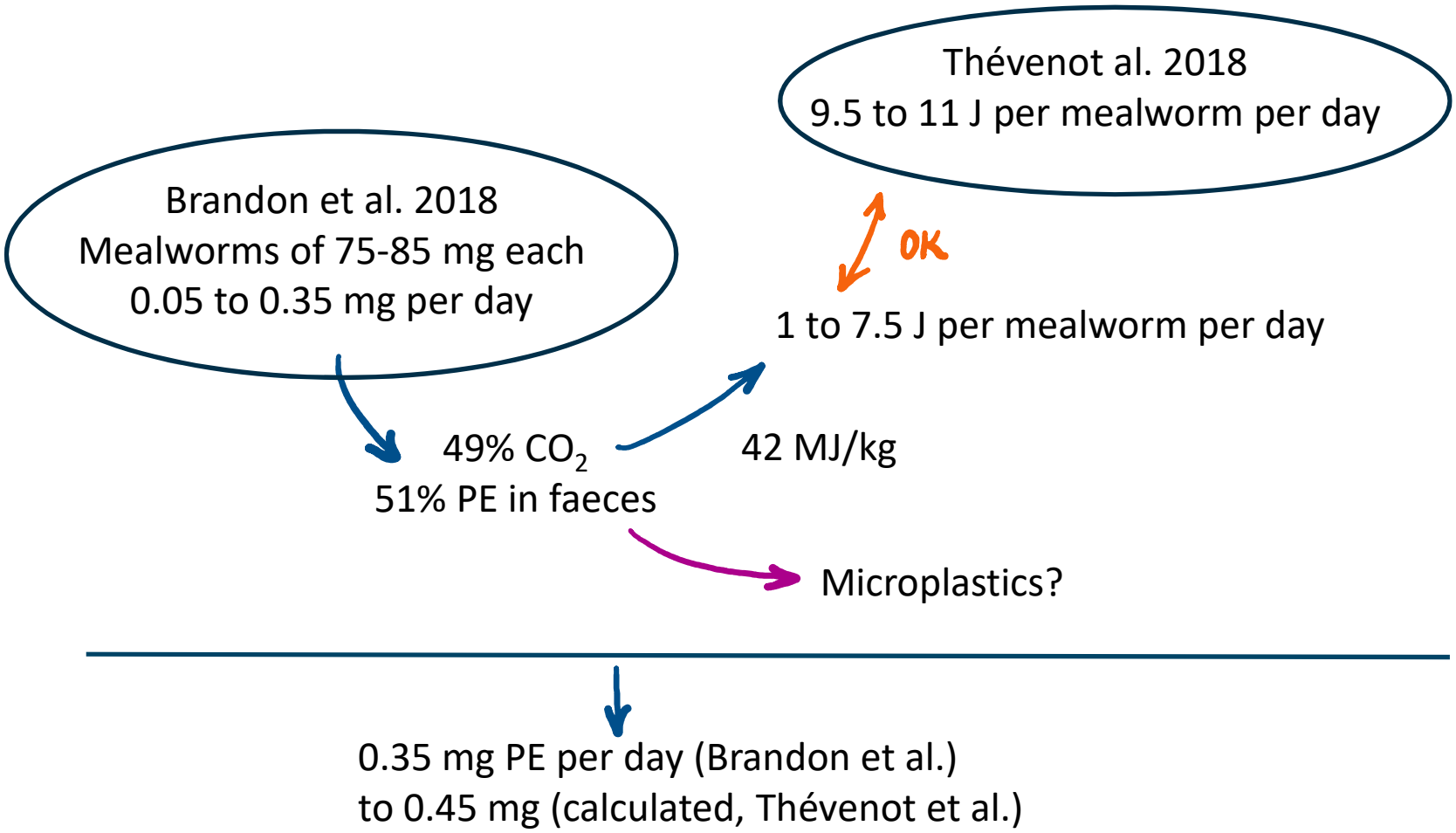
Weber, C., Pusch, S., Opatz, T. Current Biol 27, R731–45 (2017)

How do they do it?



Food for thought…

Technology potential



Thévenot, A., Rivera, J.L., Wilfart, A., Maillard, F., Hassouna, M., Senga-Kiesse, T., Le Féon, S., Aubin, J. J Clean Prod 170, 1260-1267 (2018)
Brandon, A.M., Gao, S.H., Tian, R., Ning, D., Yang, S.S., Zhou, J., Wu, W.M., Criddle, C.S. Env Sci Technol 52, 6526-6532 (2018)

Technology potential

0.35 mg PE per day (Brandon et al.)
to 0.45 mg (calculated, Thévenot et al.)

Zheng et al. (2013):
mealworms in 76 days to 176 mg

Functional unit:
complete consumption of 1 tonne of PE film (without additional food) by 35-day old mealworms in an additional 32 days

Ooninckx & de Boer (2012):
55 mWh of grid electricity
240 mWh of natural gas
0.22 L of water per mealworm

5.5 to 7.1 tonnes of mealworms required

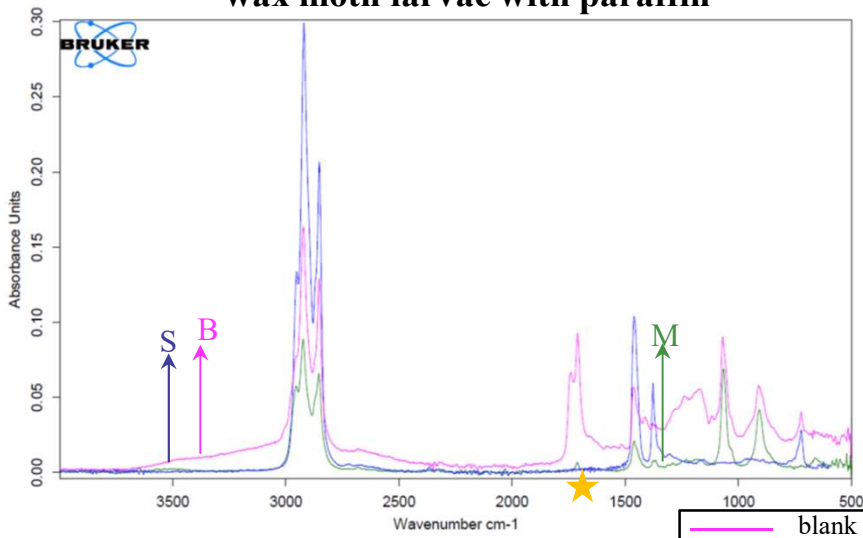
Electricity	290 EUR to	370 EUR
Natural gas	500 EUR to	642 EUR
	790 EUR to	1112 EUR per tonne of PE treated

Biomass growth?
Valorization of frass?
Revenue from biodiesel?

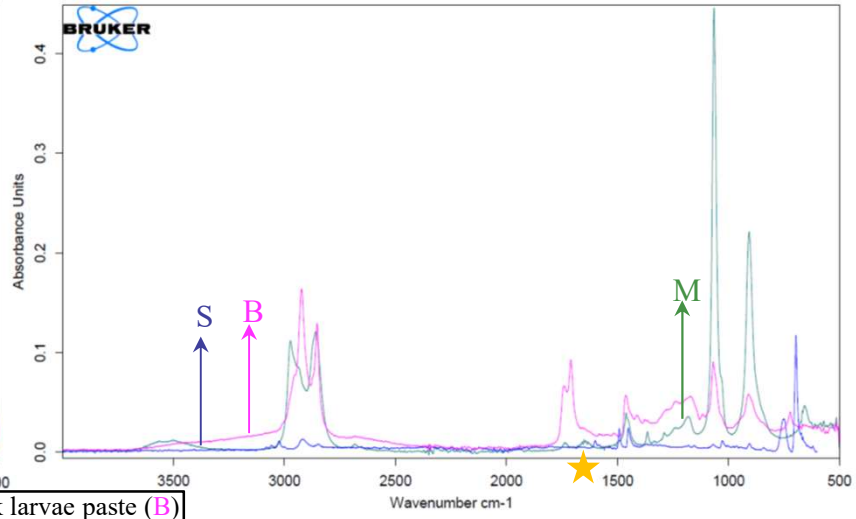
Zheng, L., Hou, Y., Li, W., Yang, S., Li, Q., Yu, Z. Appl Energ 101, 618-621 (2013).
Oonincx, D.G.A.B., de Boer, I.J.M. PLOS One 7(12), e51145 (2012)

Yet… there may be value

paste$_{GWM}$_paffin
wax moth larvae with paraffin

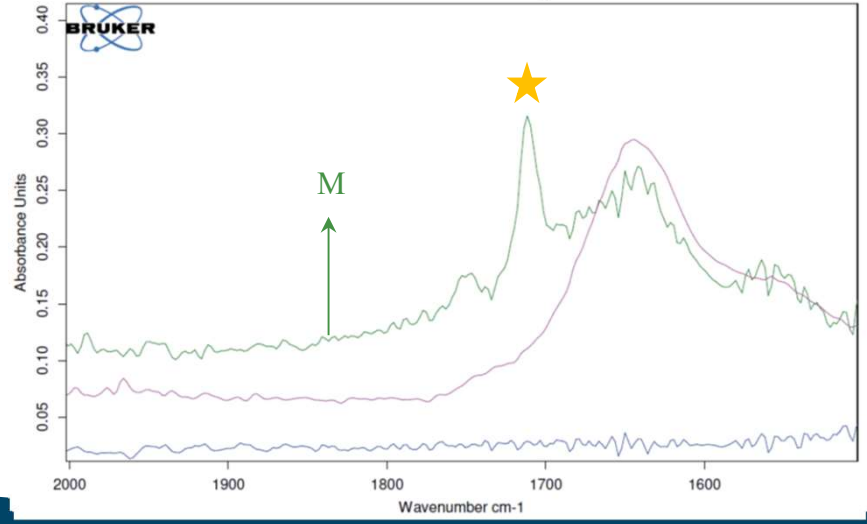


paste$_{GWM}$_PS
wax moth larvae with polystyrene

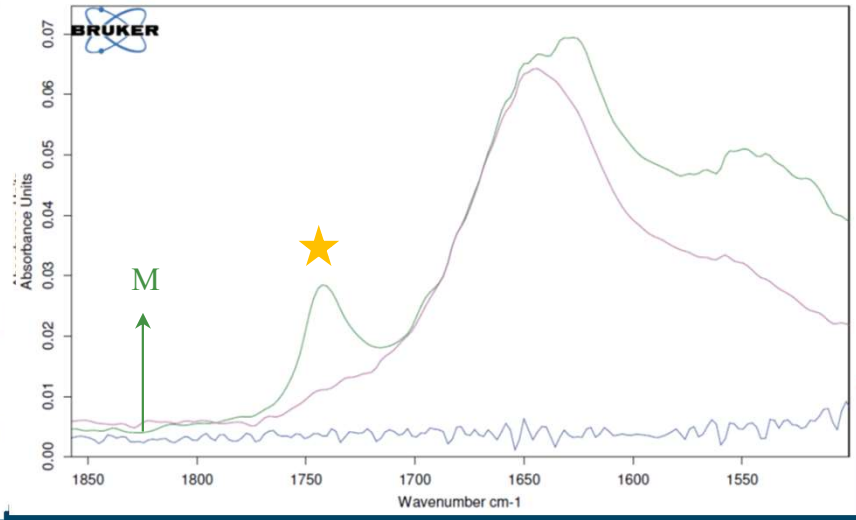


blank larvae paste (B)
blank substrate (S)
treated mixture (M)

paste$_{MW}$_paffin
mealworms with paraffin



paste$_{MW}$_PS
mealworms with polystyrene



Conclusions

- Destruction (degradation) of PE is not OK, especially not without energetic valorization
- No feasible remediation technology
  - Preference for other nutrition (even cannibalism)
  - Ubiquity and abundance issues
  - Microplastics

- Fundamental biological insights are interesting
- Indications of paraffin functionalization: promising for biochemical process?

Invitation for collaboration

Pieter Billen
BioGEM research group
University of Antwerp (Belgium)
pieter.billen@uantwerp.be

Sabrina Spatari
Civil and Environmental Engineering
Technion (Israel)
sabrinas@technion.ac.il

Serge Tavernier
BioGEM research group
University of Antwerp (Belgium)
serge.tavernier@uantwerp.be


University
of Antwerp