



LABORATOIRE
SCIENCES POUR
L'ENVIRONNEMENT
UMR 6134 SPE



Low environmental impact protection systems to reduce the vulnerability of buildings to fire at the wildland-urban interface

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Co-supervisor:

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Thesis context

- Probability of catastrophic wildfires will increase from 30 to 60% by the end of the century¹
- Areas at the wildland-urban interface (WUI) are responsible of ever-larger fires²
- In these areas, wood-based elements present in building structures are one of the main responsible of fire spread³. These structural elements are increasing in number over the years⁴



Example of WUI fire

(1) Climate Change 2022:Impacts, Adaptation and Vulnerability - Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change;
(2) Chas-Amil, ML et al. 2013, Applied Geography, 43, pp.127-137;
(3) Hasburgh, LE et al. Fires, 2017, 53 (2) , pp.517-534;
(4) Baranovskiy, N.V. et al. Processes 2022, 10, 263

Thesis context and aim

How to fight the risk of a WUI fire ?

- Creation of a defensible space around houses
- Removal of any flammable vegetation or fuel, as well as a good maintenance
- Implementation of appropriate materials or their adequate protection



Fire retardant treatments for wood

- Impregnation
- Surface modification
- Coating



Development of a low environmentally impact fire protection coating for wood

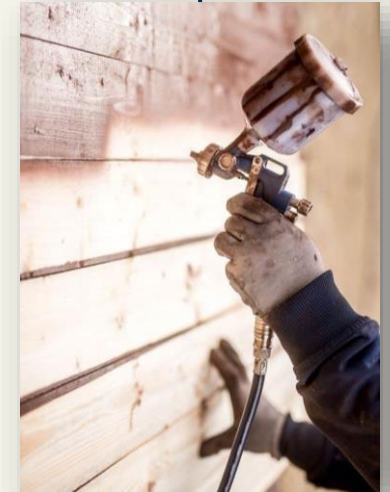
5) Àgueda Alba, Vacca Pascale, Planas Eulalia, Pastor Elsa (2023) Evaluating wildfire vulnerability of Mediterranean dwellings using fuzzy logic applied to expert judgement. International Journal of Wildland Fire 32, 1011-1029.

Strategy

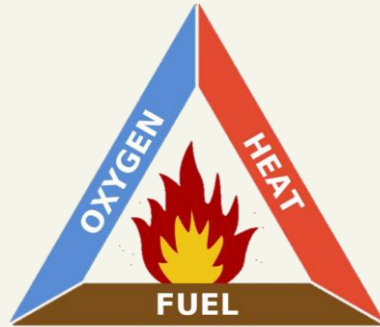
Biomass
extraction

FR system
development

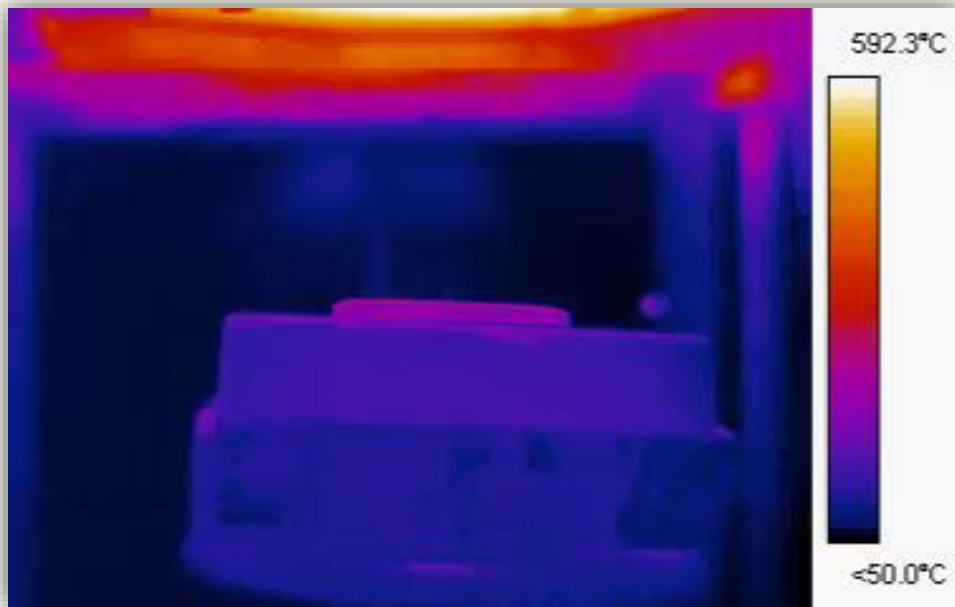
Application
and fire tests



Introduction: Fire and Flame Retardants strategies



Fire triangle

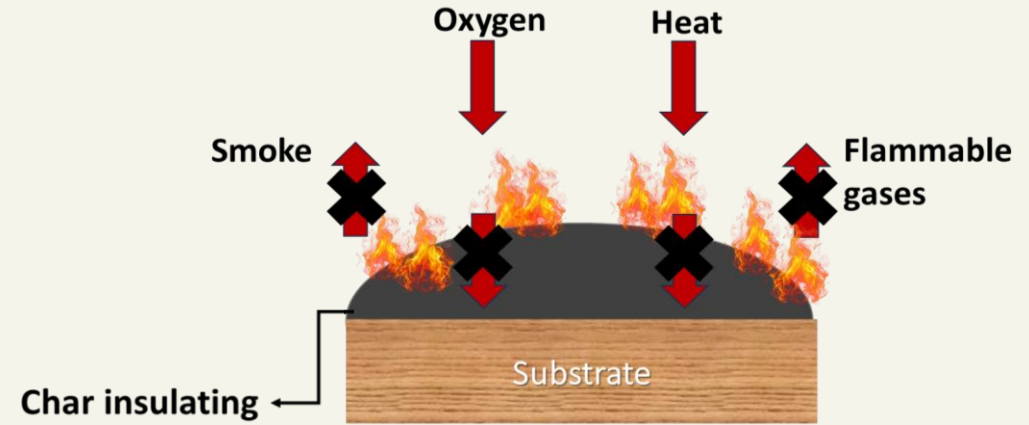
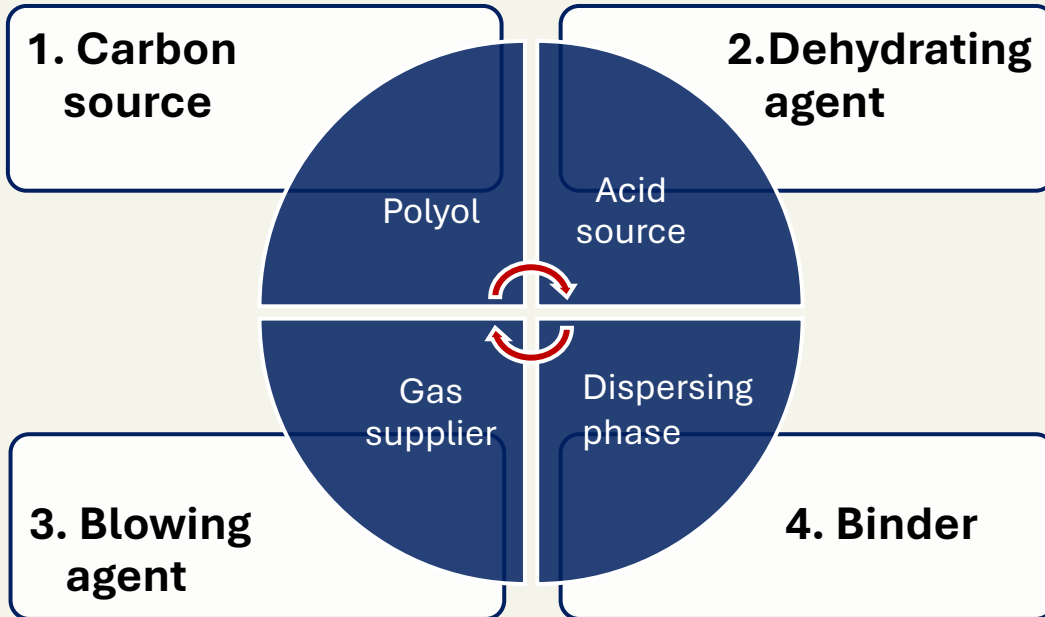


Flame Retardant (FR) approaches

- Dilution through compounds able to generate inert gases during decomposition
- Heat subtraction by endothermic reactive compounds: $\text{Al}(\text{OH})_3$, $\text{Mg}(\text{OH})_2$, etc.)
- Flame poisoning by active radicals: e.g. halogen-based FR, Phosphorus FR
- Formation of a protective char layer: Intumescent FR coatings

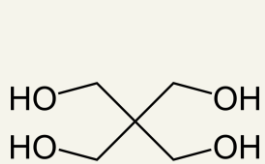
Introduction: Intumescent Flame Retardant (IFR) coatings

Intumescent Flame Retardant (IFR) coating

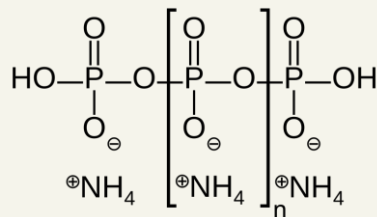


Advantages:

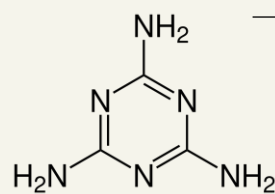
- Easy application
- Cheap
- Efficient protection for wood



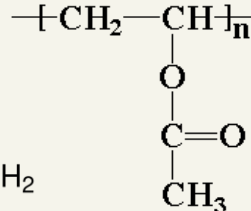
1. PER



2. APP



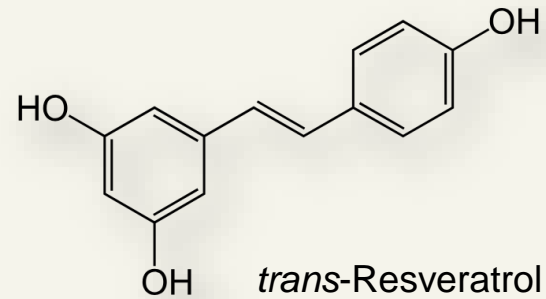
3. Melamine



4. PVA

Resveratrol as precursor

Wine industry wastes

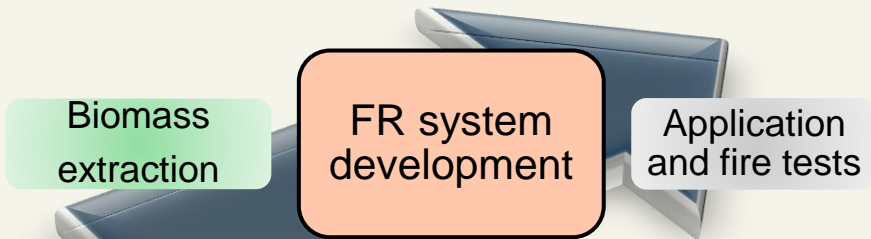


Evidenced properties in existing resveratrol-based materials:

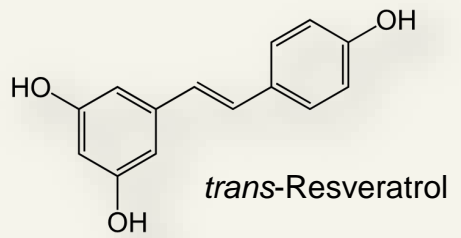
- Very high thermal resistance
- Good charring ability
- High durability

-
- 6) Lu *et al.* Biomass-based epoxy resin derived from resveratrol with high temperature resistance and intrinsic flame retardant properties, *Ind. Crops and Prod.*, 187 (B), 2022, <https://doi.org/10.1016/j.indcrop.2022.115500>
 - 7) Zhang *et al.* (2019). Resveratrol-based tri-functional benzoxazines: Synthesis, characterization, polymerization, and thermal and flame retardant properties. *European Polymer Journal*, 116. <https://doi.org/10.1016/j.eurpolymj.2019.04.036>
 - 8) Cambrea *et al.* (2017), Processable cyanate ester resin from *Cis* resveratrol. *J. Polym. Sci. Part A: Polym. Chem.*, 55: 971-980. <https://doi.org/10.1002/pola.28457>

Flame Retardant system development

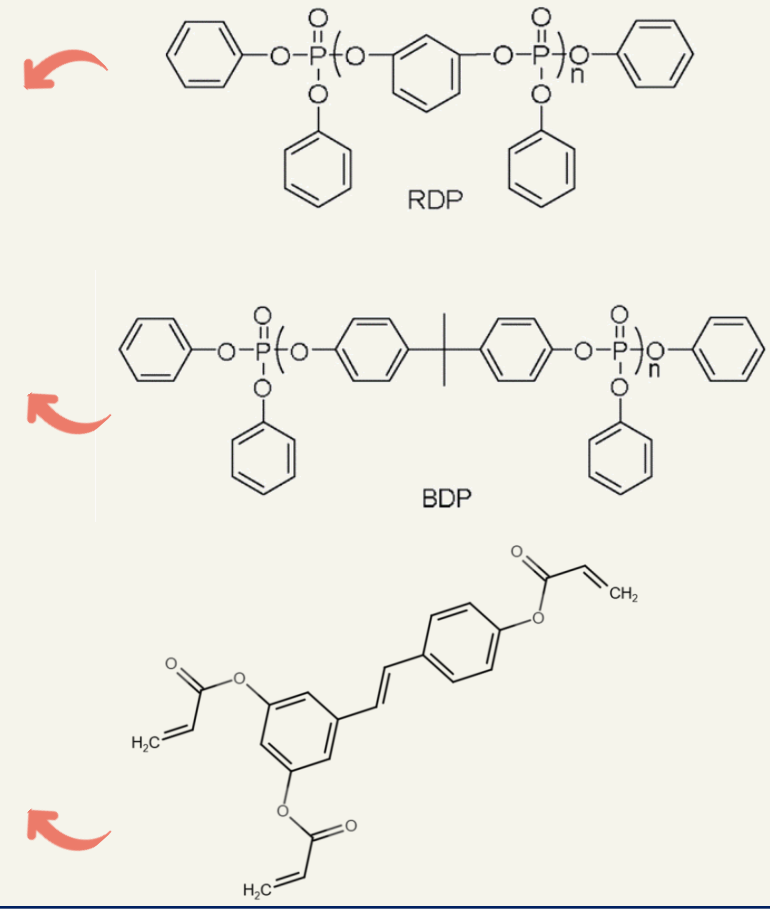


Chemical modification of resveratrol



Synthesis of a Polymer containing phosphorus as additive in FR paints

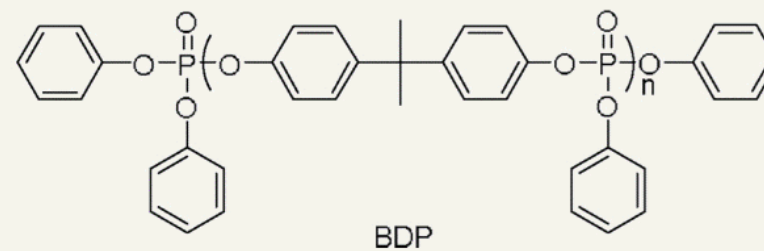
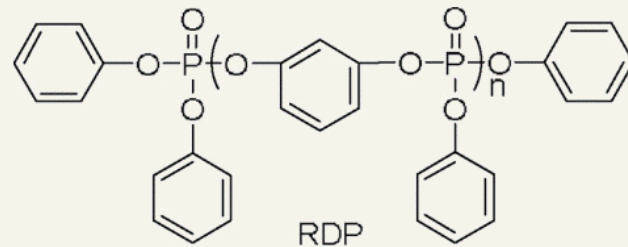
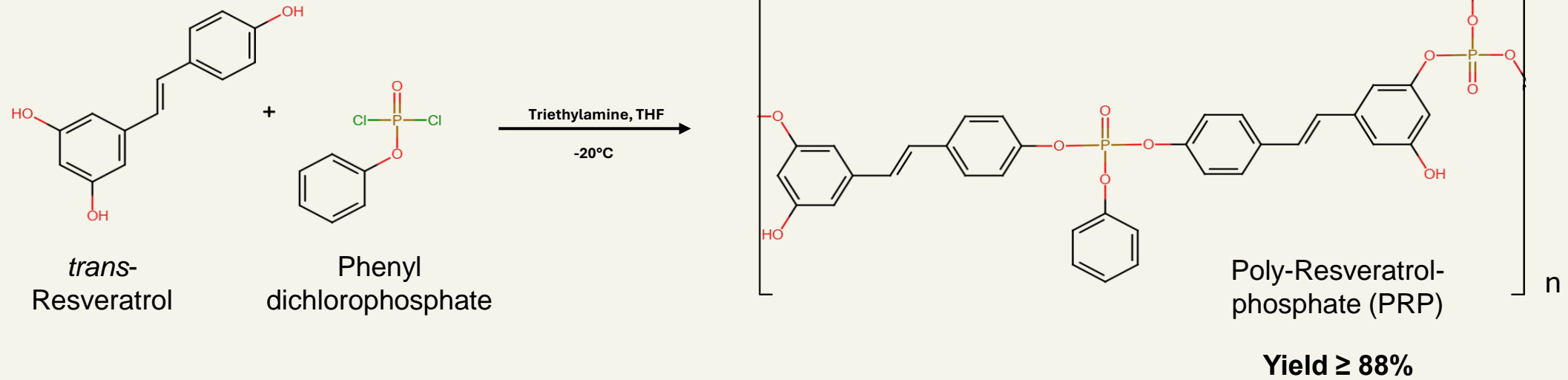
Synthesis of a UV-curable tri-acrylate as a new binder for FR coatings



9. Liu et al. (2018). Mechanism of thermal degradation of aryl bisphosphates and the formation of polyphosphates. Journal of Analytical and Applied Pyrolysis, 133, 216–224. <https://doi.org/10.1016/J.JAAP.2018.03.022>

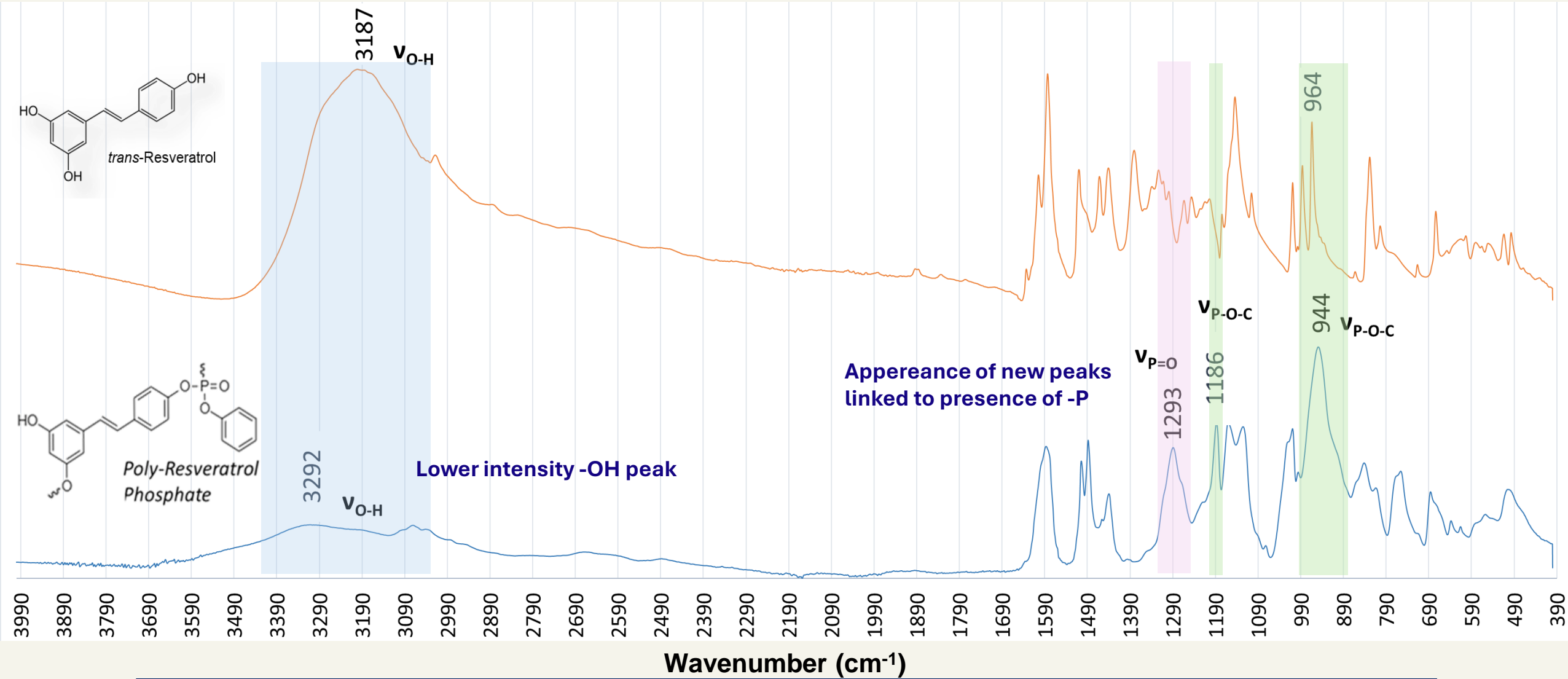
Synthesis of Poly-Resveratrol-Phosphate

Proposed synthetic pathway



9. Liu et al. (2018). Mechanism of thermal degradation of aryl bisphosphates and the formation of polyphosphates. Journal of Analytical and Applied Pyrolysis, 133, 216–224. <https://doi.org/10.1016/J.JAAP.2018.03.022>

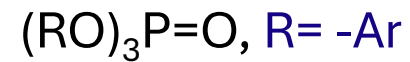
Fourier Transform Infra-Red spectroscopy (FT-IR)



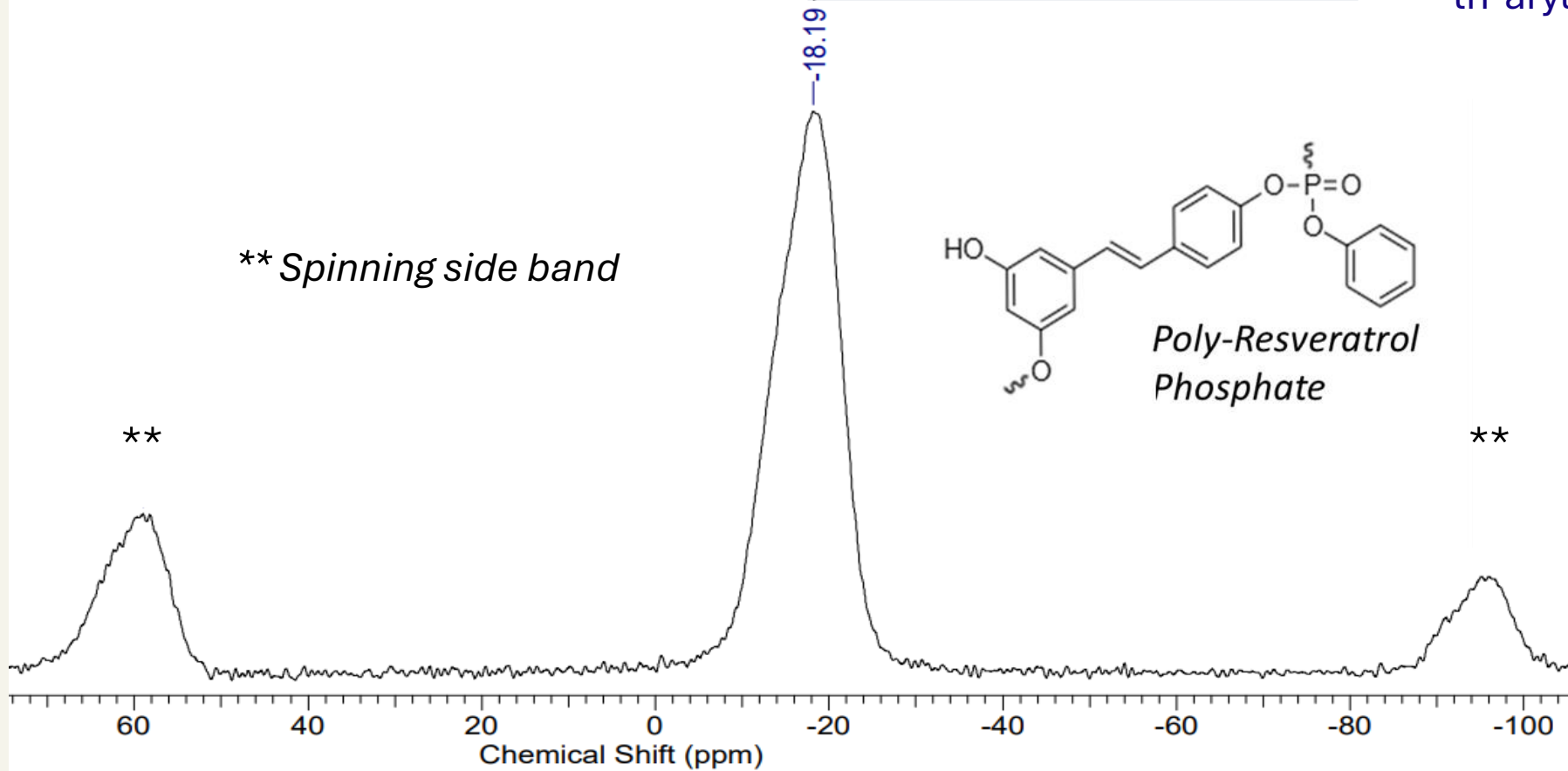
10) Renier, M. L., & Kohn, D. H. (1997). Development and characterization of a biodegradable polyphosphate. *Journal of Biomedical Materials Research*, 34(1). [https://doi.org/10.1002/\(SICI\)1097-4636\(199701\)34:1<95::AID-JBM13>3.0.CO;2-O](https://doi.org/10.1002/(SICI)1097-4636(199701)34:1<95::AID-JBM13>3.0.CO;2-O)

Nuclear Magnetic Resonance (NMR)

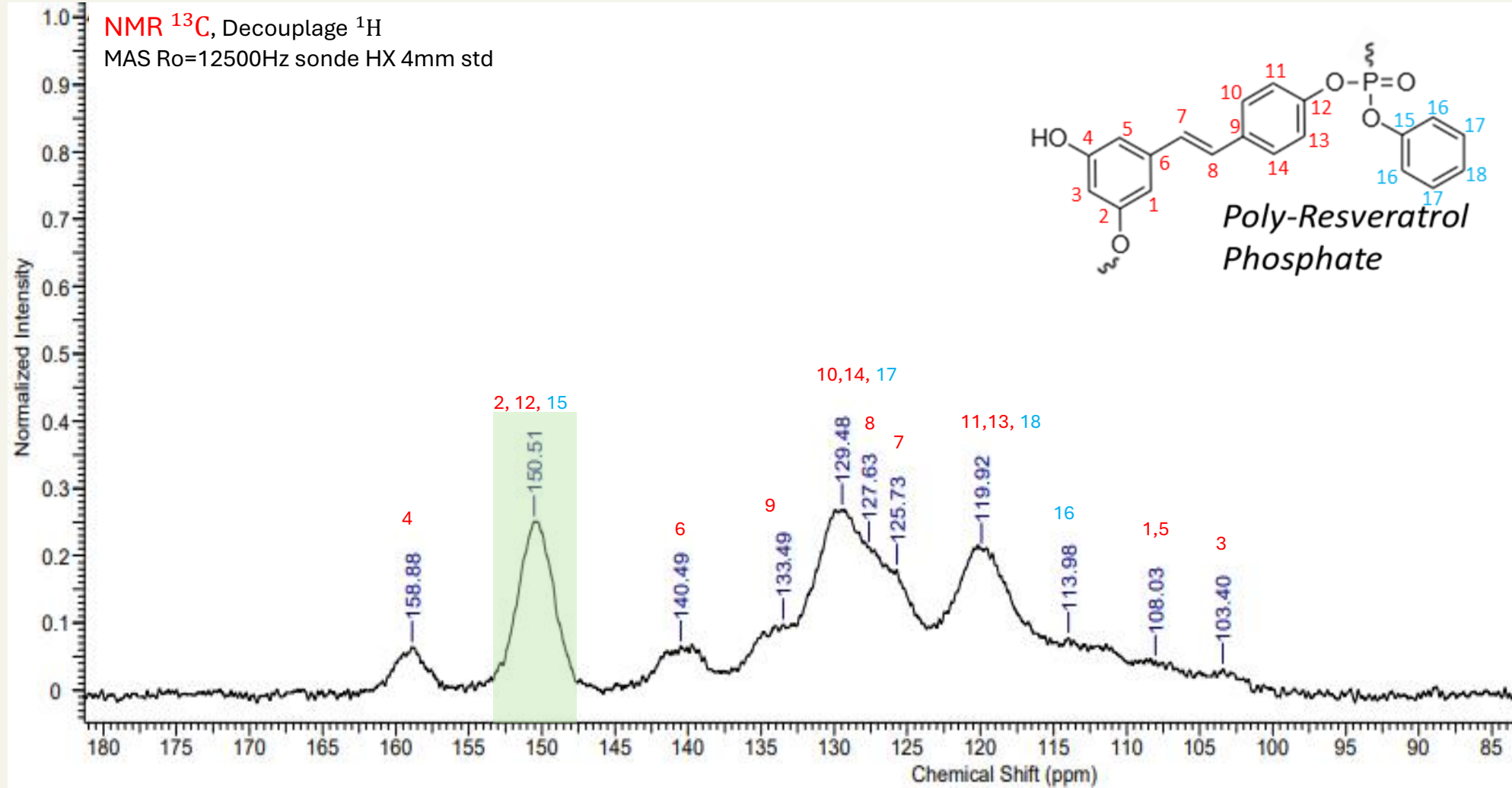
NMR ^{31}P , Decoupled ^1H
MAS $R_0=12500\text{Hz}$ sonde HX 4mm std



^{31}P ss-NMR shows one
single peak coherent with a δ
tri-aryl phosphate ester like



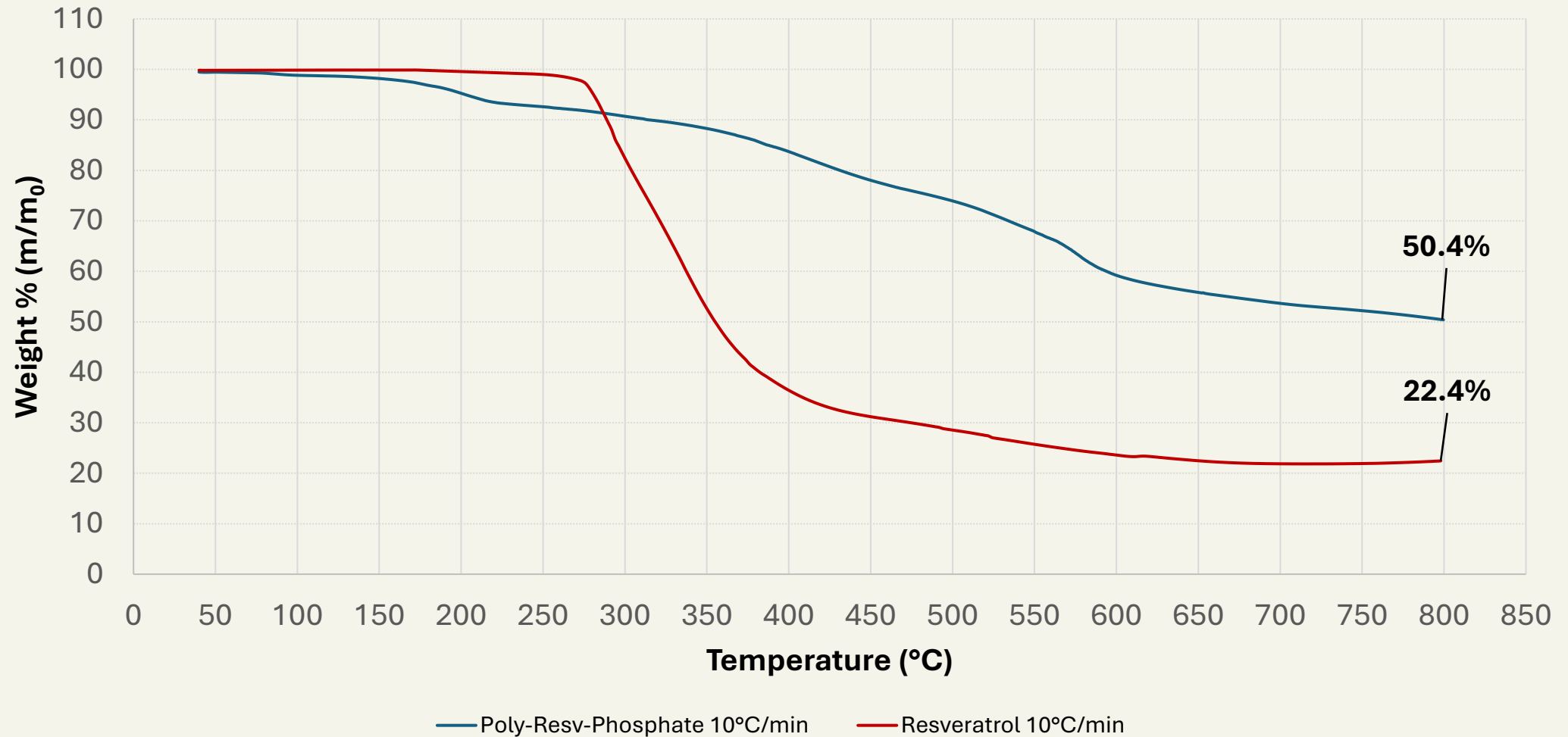
Nuclear Magnetic Resonance (NMR)



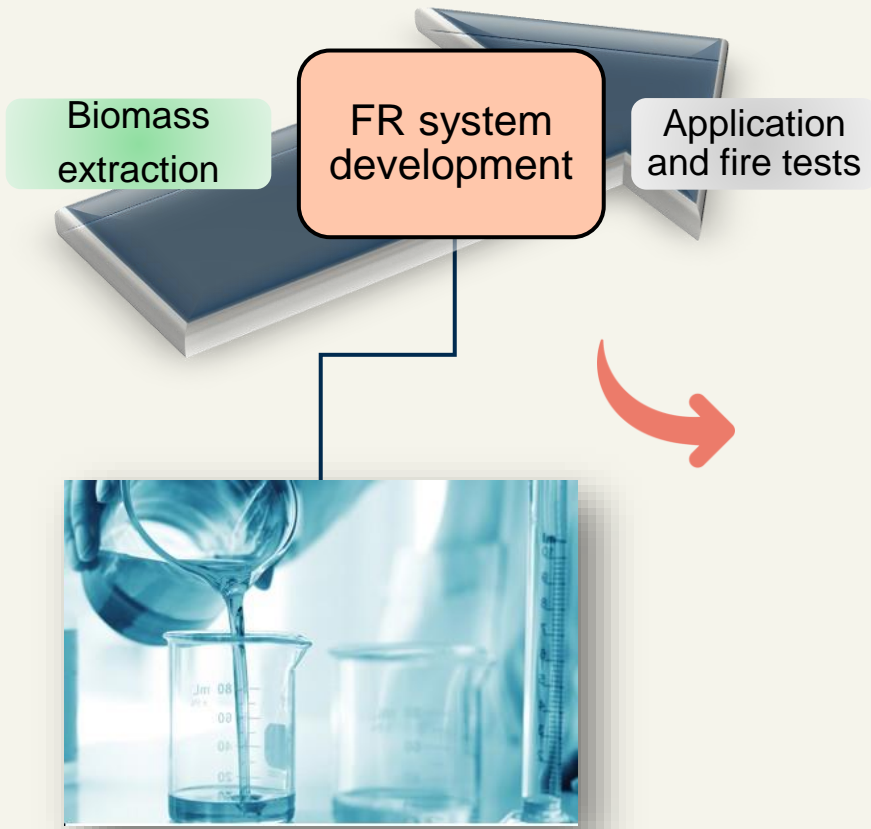
11) Xiangguo Yue, Wei Zhang, Maicun Deng, (2011). Hyper-production of ^{13}C -labeled trans-resveratrol in *Vitis vinifera* suspension cell culture by elicitation and in situ adsorption. *Biochemical Engineering Journal*, 53 (3), <https://doi.org/10.1016/j.bej.2010.12.002>.

Thermo-gravimetric analysis

TGA 10°C/min in N₂

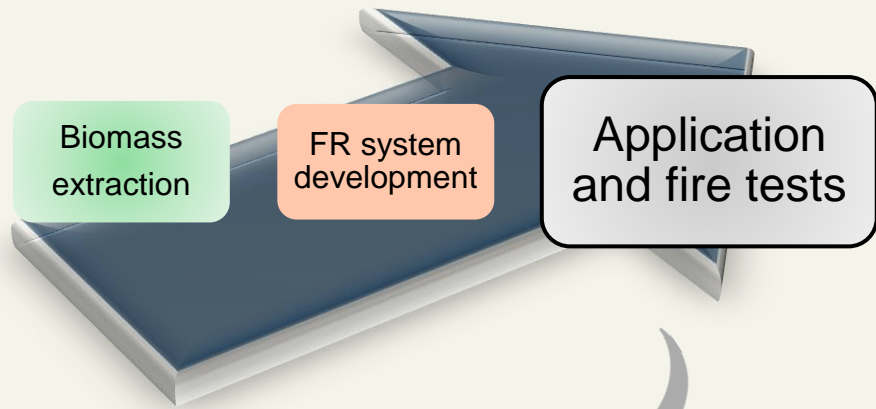


Conclusions

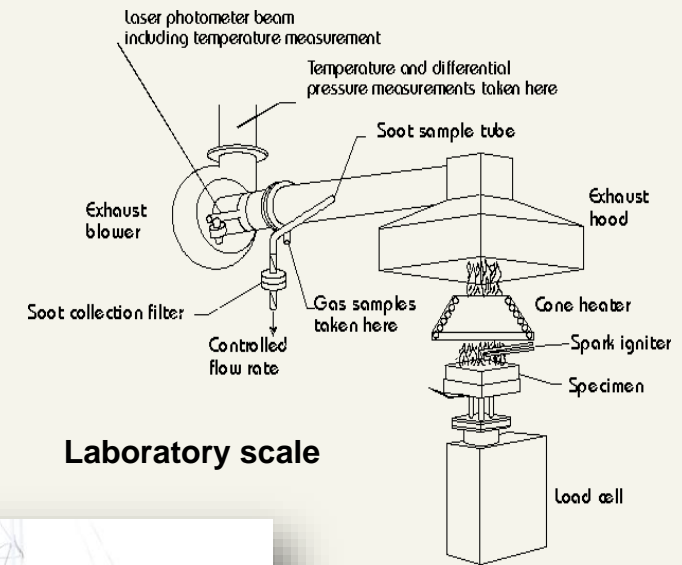


- ✓ **Synthesis of a new poly-phosphate additive from a bio-based compound**
- ✓ **Structure confirmed by FT-IR and NMR**
- ✓ **Confirmed charring ability and thermal stability**

Outlooks



- **Formulation optimization and laboratory scale fire tests**
- **Perform fire test on real scale**



➤ **Test additive fire properties in different matrices:**

- Bio-based epoxy
- Acrylic or PVA
- Resveratrol-based acrylic resin developed



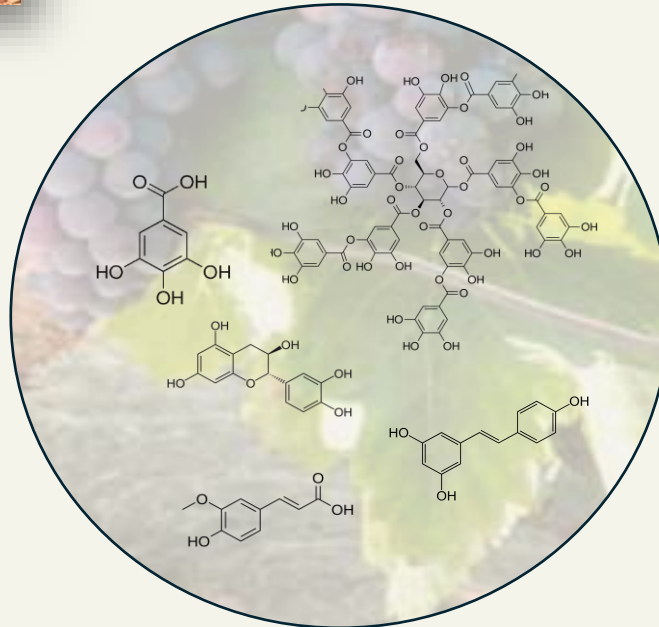
**Real scale
Platform EXPLORII
Université de Corse**

Outlooks

Wine industry wastes



High content of polyphenols



Biomass extraction

FR system development

Application and fire tests

- Investigate how develop a similar additive from a set of extracted polyphenols
- Develop an IFR formulation using these extracts

Acknowledgements



MITI

**Mission pour les Initiatives
Transverses et Interdisciplinaires**




Thesis supervisors:

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Co-supervisor:

Dr. F. Samyn (UMET)



**Thank you for the
attention!**

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