FORMALDEHYDE DEGRADATION IN AMBIENT AIR WITH IMMOBILIZED *OGATAEA POLYMORPHA* IN A HYBRID SOL-GEL COATING

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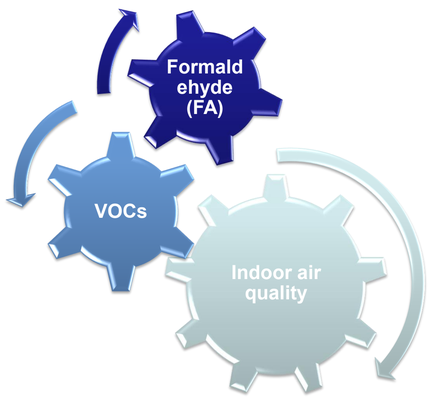
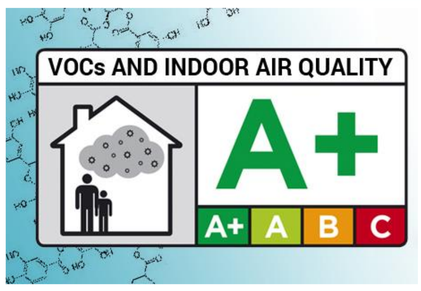
BACKGROUND

Indoor air pollution of residential buildings and workplaces is a major concern of nowadays. Toxic pollutants such as formaldehyde, or benzene which have carcinogenic effects on health, are constantly released from different construction and decoration materials and/or household's products [1,2]. The development of bioactive coatings incorporating biomolecules able to capture and degrade this toxic compound is of major interest. However, the conservation of their degradative activity is crucial throughout time [3]. The incorporation of whole cells within a sol-gel matrix can offer a more favorable environment compared to isolated and purified enzymes, that enhances enzyme stability and supports cofactor regeneration, both essential for a durable enzymatic activity, while also eliminating the costs associated with enzyme extraction and purification [4]

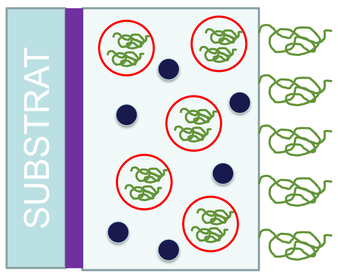


Formaldehyde Health effects: mucosal, respiratory, and ocular irritation, potential **carcinogenic**
- Typical indoor range : **10-90 µg/m³**,
- Poorly ventilated or recently renovated spaces: **~250 µg/m³**
- Irritation threshold: **~125 µg/m³**

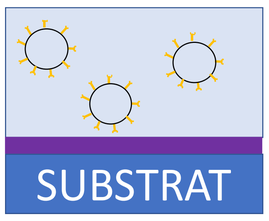
The immobilization of freeze-dried yeast (*Ogataea polymorpha MUCL 27761)* cells in a sol-gel matrix for formaldehyde degradation is herein studied. The main steps of this study were : design and characterization of sol-gel biocoating incorporating O. polymorpha, quantification assessment of the formaldehyde elimination in solution and proof of concept of the applicability on a case study in gas phase. Cellulose paper chromatography was used as substrate for the biocoating, applied by spray. Covered substrates, prepared with 2 different sol-gel formulations, were tested. Formaldehyde degradation ability of the coatings is evaluated in aqueous solution. Results proved that bioactive coatings are a simple, cheap, and environmentally friendly technology, efficient to biologically improve de quality of indoor air and even water.



Improvement of indoor air quality by VOC degradation



Use of whole feeze-dried microorganism incorporated in sol-gel coatings



Deposition of the coatings on the surface of substrate

⇒ ***Ogataea polymorpha*** **incorporated in sol-gel coating for formaldehyde decontamination**

EXPERIMENTAL PLAN

OPTIMIZATION OF O. POLYMORPHA PRODUCTION AND ENZYMATIC ACTIVITY

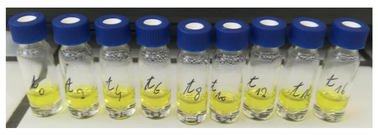
- Culture media : YG (yeast extract + glucose) and Ma (Malt), with and without formaldehyde (1, 2, 5 and 10 mM) during the growth phase

IMMOBILIZATION OF O. POLYMORPHA IN SOL-GEL MATRIX

- Evaluation of two sol-gel formulation with formaldehyde aqueous solution
- Proof of concept of formaldehyde gaseous phase degradation with wood whool

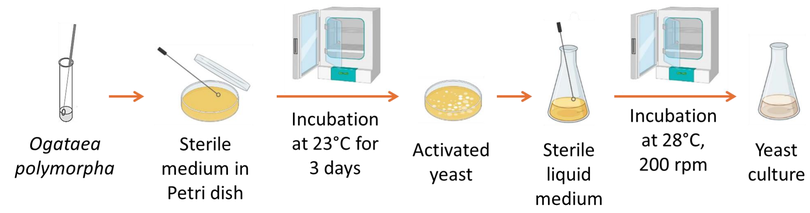
FORMALDEHYDE DEGRADATION EFFICIENCY

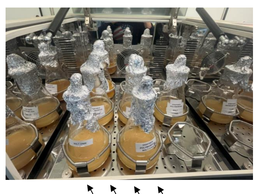
- Study of formaldehyde degradation using NASH reagent
- Colorimetric detection of the yellow complex 3,5-diacetyl-1,4-dihydroxydrolutidine (DDL) at 412 nm



COATING PREPARATION

MICROORGANISM'S CULTURE AND PREPARATION



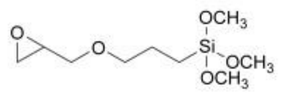

Freeze drying


Freeze drying allow to obtain water dispersible particles
Microorganism is biologically inactivated but enzymes activity is recovered after re-hydration
Enzymatic activity is sensitive to temperature, pH, solvents, UV and ultrasounds

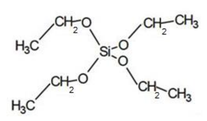
BIO-ACTIVE COATING PREPARATION

Sol-gel precursors

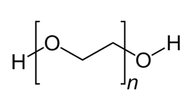
GPTMS

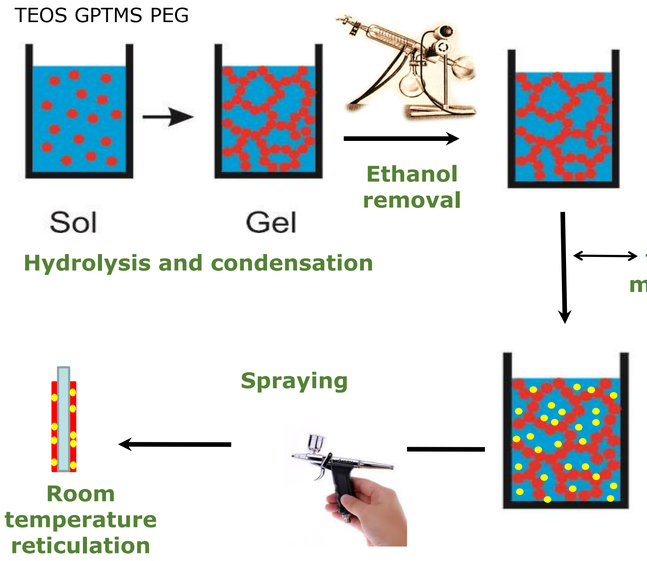


TEOS



PEG





RESULTS AND DISCUSSION

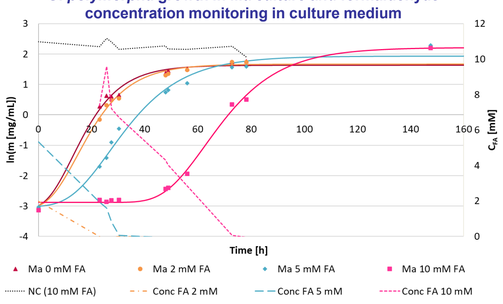
YEAST GROWTH AND FORMALDEHYDE DEGRADATION STUDY

Growth dynamics is modelled by the **Gompertz** equation :

$$\ln(m) = \ln(m_0) + (\ln(m_{max}) - \ln(m_0)) \cdot \exp\left(-\exp\left(\frac{\mu_{max} \cdot e \cdot (t_{lag} - t)}{\ln(m_{max}) - \ln(m_0)} + 1\right)\right)$$

	YG				Ma			
FA	0 mM	2 mM	5 mM	10 mM	0 mM	2 mM	5 mM	10 mM
m_0 [mg/mL]	0.03	0.04	0.03	0.02	0.04	0.05	0.05	0.06
m_{max} [mg/mL]	2.18	2.90	6.59	n.d.	5.13	5.30	6.88	9.18
μ_{max} [h^{-1}]	0.22	0.12	0.11	n.d.	0.17	0.16	0.12	0.12
t_{lag} [h]	11.24	16.01	81.60	n.d.	2.88	3.74	11.70	47.25

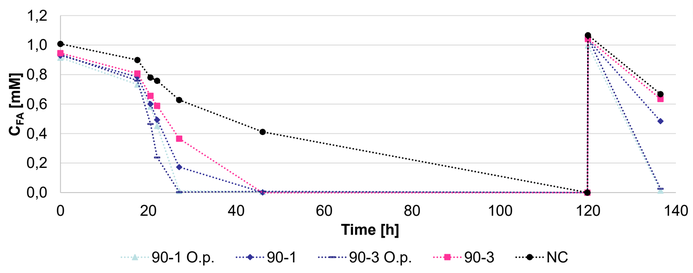
O. polymorpha growth in Ma culture and formaldehyde concentration monitoring in culture medium

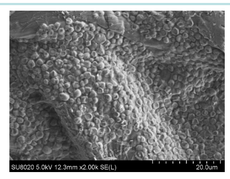


- FA slows growth: ↓ μ_max, ↑ t_lag
- YG medium: no growth at 10 mM (toxicity threshold)
- Ma medium: supports growth up to 10 mM FA; higher m_max and shorter t_lag
- Ma offers better environment
- *O. polymorpha* shows high FA tolerance

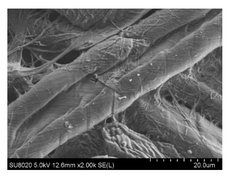
EVALUATION OF COATINGS EFFICIENCY

Formaldehyde degradation kinetics in aqueous solution after biocoating deposition

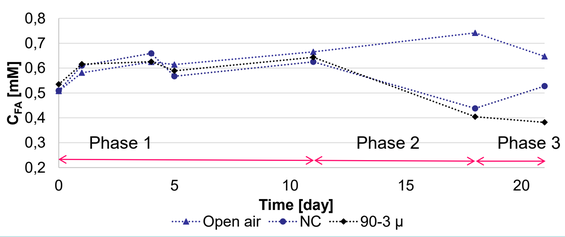


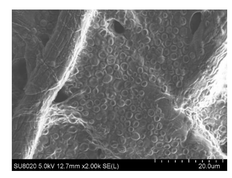

SEM photography of the cellulose paper support with 90-1 coating formulation

- **Complete degradation of the formaldehyde after 50 hours,**
- **Maintenance of activity after a second injection of formaldehyde**


SEM photography of the cellulose paper support without coating

Formaldehyde degradation kinetics in gaseous phase after biocoating deposition with insulation hood (MDF) fiber




SEM photography of the cellulose paper support with 90-3 coating formulation

CONCLUSIONS

- ✓ Developed **bioactive sol-gel coatings** with *O. polymorpha* for FA removal
- ✓ Demonstrated **FA elimination** in both liquid and gas phase
- ✓ **Acclimation to FA** improved yeast performance
- ✓ **Prove of concept** with insulation wood fiber confirmed feasibility for geseous degradation of FA

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[2]Salthammer *et al* (2010) *Chem. Rev.*, 110(4), 2536–2572.
[3]Anthony (1983) 8(9), Eds. Kluwer Academic Publishers, 342–343.
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