Workshop “Innovative technologies for sustainable management of urban and industrial waste streams”

Pyrolysis characteristics of waste mixtures containing organic food and gardening pruning

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Introduction and motivation

Biowastes: 40 % total

Gardening pruning & food waste

Chemical valorisation

Thermochemical valorisation

Biological valorisation

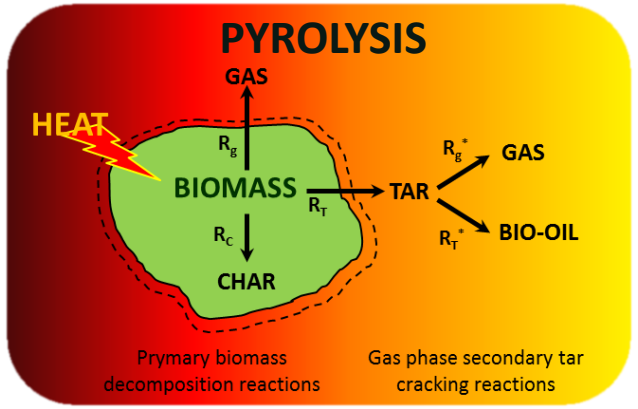
High value-added bioproducts & biofuels

Introduction and motivation

Gardening pruning & food waste

$C_xH_yO_z$

Cellulose
Hemicellulose
Lignin



GAS (10-30 wt.%)

CO
CO_2 H_2
C_1-C_4

CHAR (10-35 wt.%)

BIO-OIL (10-75 wt.%)

Reaction Conditions:

- ✓ **Temperature** (≈ 500 ˚C)
- ✓ **Heating rate** (10^3-10^4 K/s)
- ✓ **Vapors residence time** (≈ 1-2 s)

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"Fast-Pyrolysis"

Bio-oil properties:

- ➢ High water content (≈ 25 wt.%)
- ➢ High oxygen content (≈ 50 wt.%)
- ➢ Low HHV (≈ 17 MJ/kg)
- ➢ High acidity (pH = 2.5)
- ➢ Low stability

…

Upgrading

Catalytic fast-pyrolysis

Upgraded bio-oil

HDO

High value-added bioproducts and bio-fuels

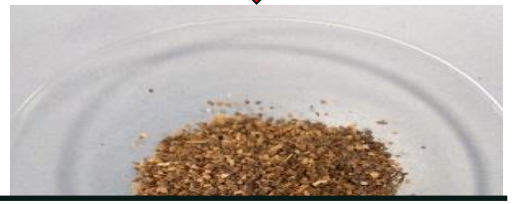
Feedstock and catalyst characterization

Feedstock characterization

Gardening Pruning

Food waste (**OFMSW**)

Dried, milled and sieved up to 0,5-1mm



	Proximate analysis (db, wt.%)				Elemental analysis (db, wt.%)				
	Moisture	**Volatile matter**	**Ash**	**Fixed Carbon**	**C**	**H**	**N**	**S**	**O**
Garden Pruning	1,2	82,5	3,3	14,2	48,5	5,9	1,4	0	40,8
OFMSW	1,1	70,5	5,6	24,0	48,6	6,0	1,3	0	38,6

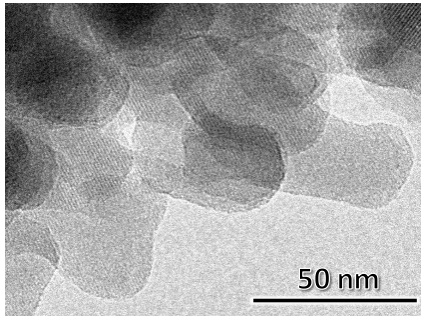
db: dry basis

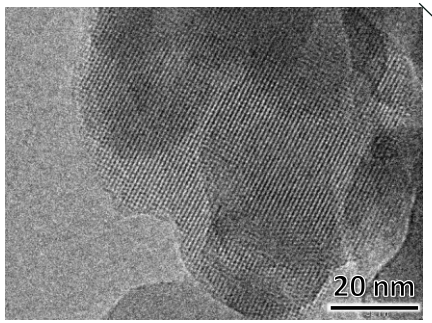
Feedstock and catalyst characterization

Catalyst characterization

Physicochemical properties of the catalyst

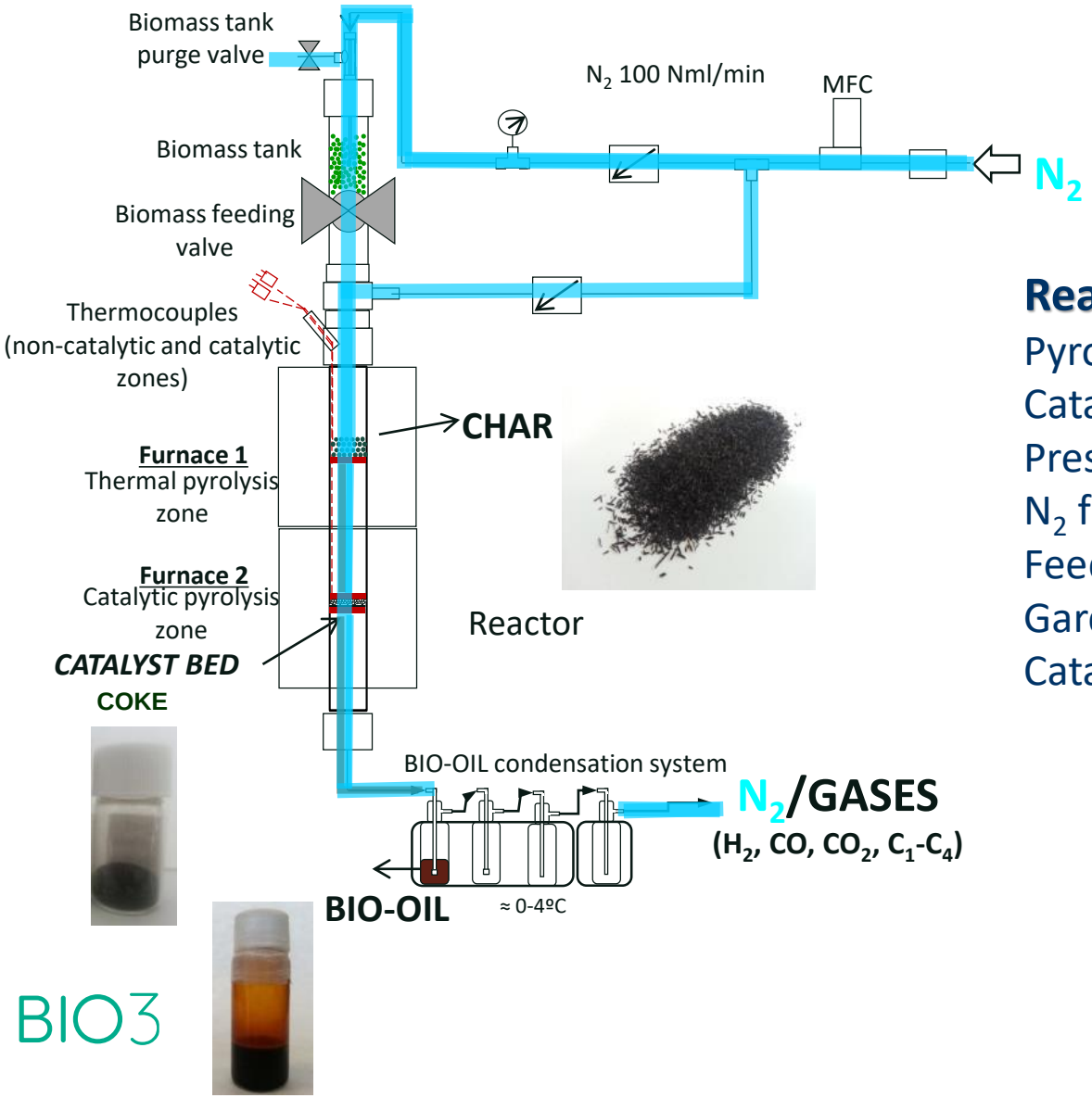
Sample	S_{BET} (m^2/g)	S_{micro} (m^2/g)	$S_{meso+ext}$ (m^2/g)	V_T (cm^3/g)	V_{micro} (cm^3/g)	$V_{meso+ext}$ (cm^3/g)	Si/Al Ratio
n-ZSM-5	395	335	60	0,372	0,151	0,221	42





Pelletized and sieved up to 0,25-0,18 mm

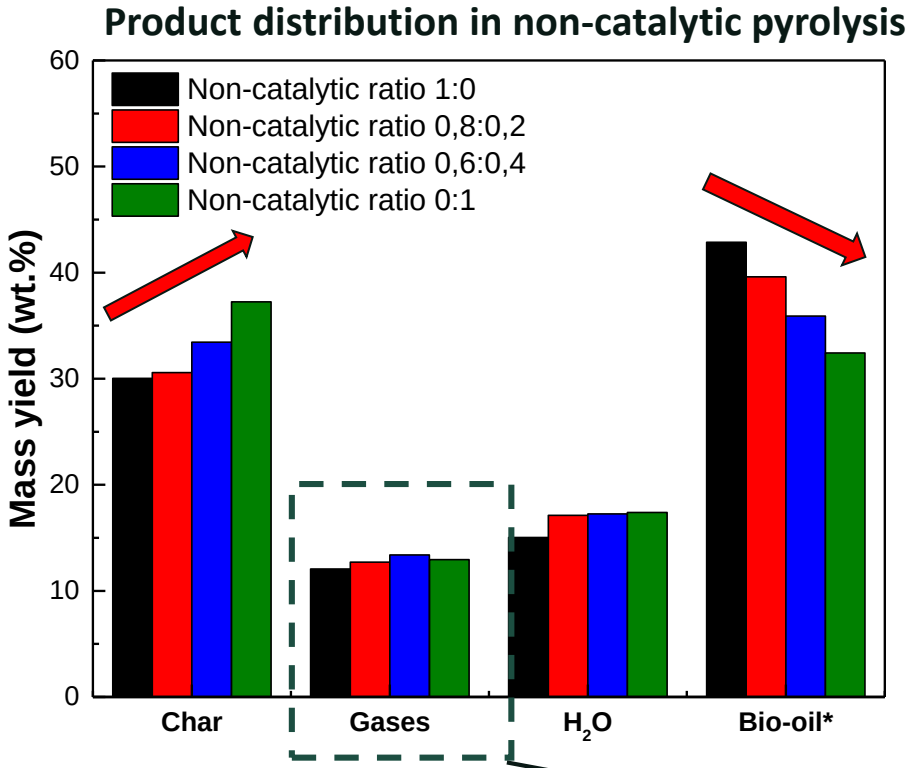
Experimental fast pyrolysis lab-scale set up



Reaction conditions:

Pyrolysis temperature: 500 ˚C
Catalyst bed temperature: 450 ˚C
Pressure: 1 atm
N_2 flow rate: 100 Nml/min
Feedstock: 5 g
Garden pruning/OFMSW ratios: 1:0; 0,8:0,2; 0,6:0,4; 0:1
Catalyst bed: 2 g n-ZSM-5 (40 wt% catalyst/Feedstock ratio)

Effect on the garden pruning/OFMSW ratio



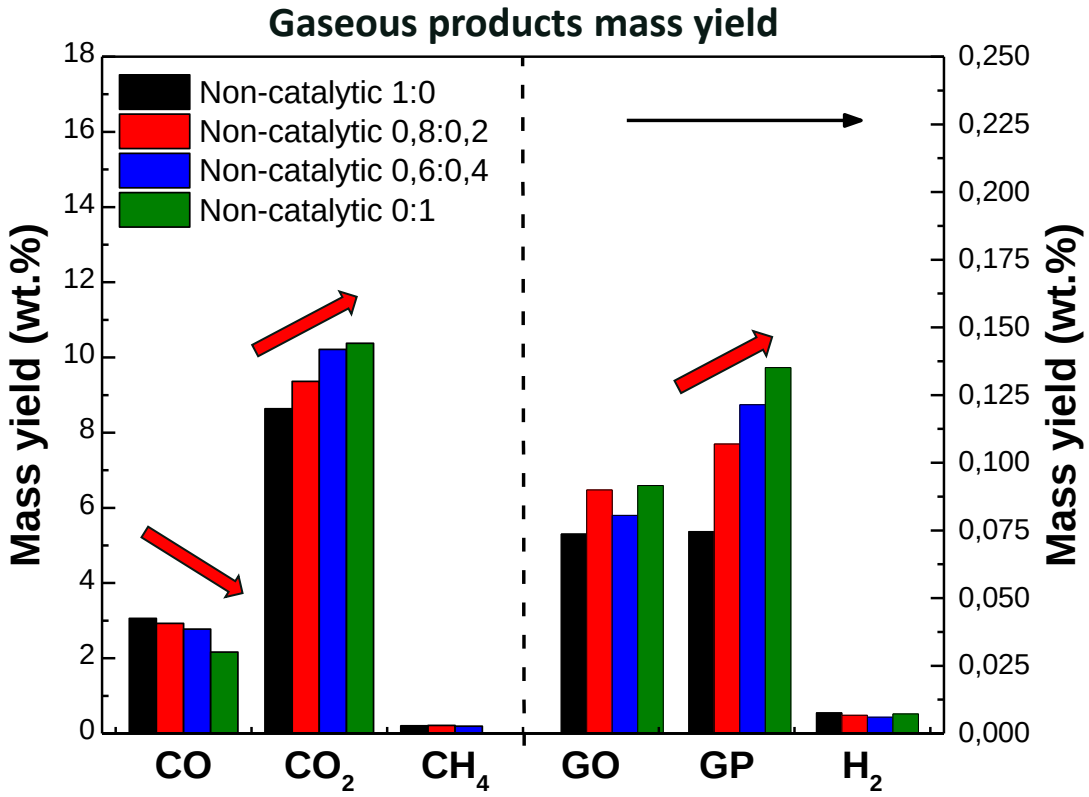
Ratio 1:0 → 100 wt.% garden pruning
Ratio 0,8:0,2 → 80 wt.% garden pruning, 20 wt.% OFMSW
Ratio 0,6:0,4 → 60 wt.% garden pruning, 40 wt.% OFMSW
Ratio 0:1 → 100 wt.% OFMSW

Higher OFMSW contents lead to:

- Similar gas yield, but with more CO_2 and light paraffins.

Higher OFMSW contents lead to:

- More char and less bio-oil produced with the increment of the food waste ratio, in accordance with the volatile matter and fixed carbon data.



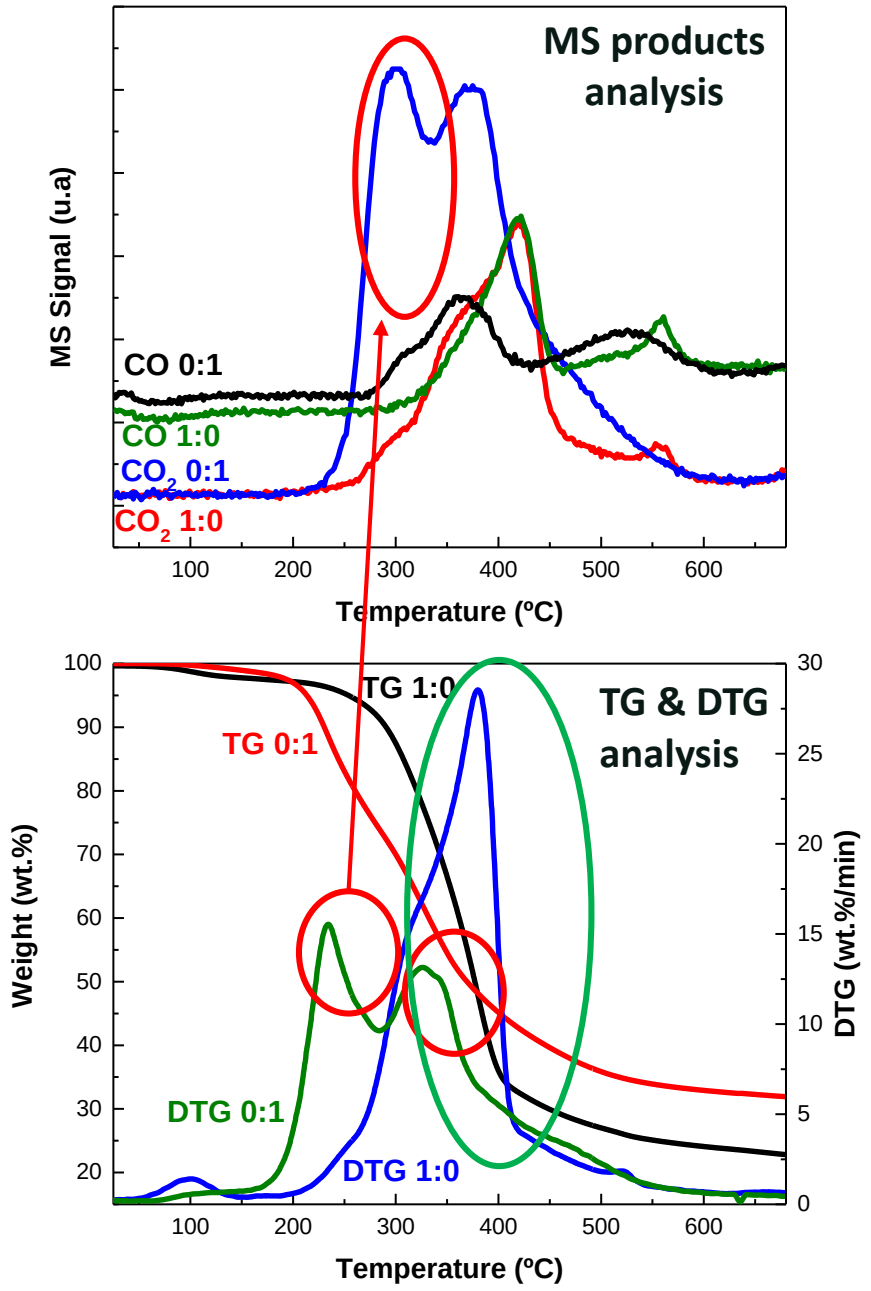
BIO3

Effect on the garden pruning/food waste ratio: TG/MS analysis

Results

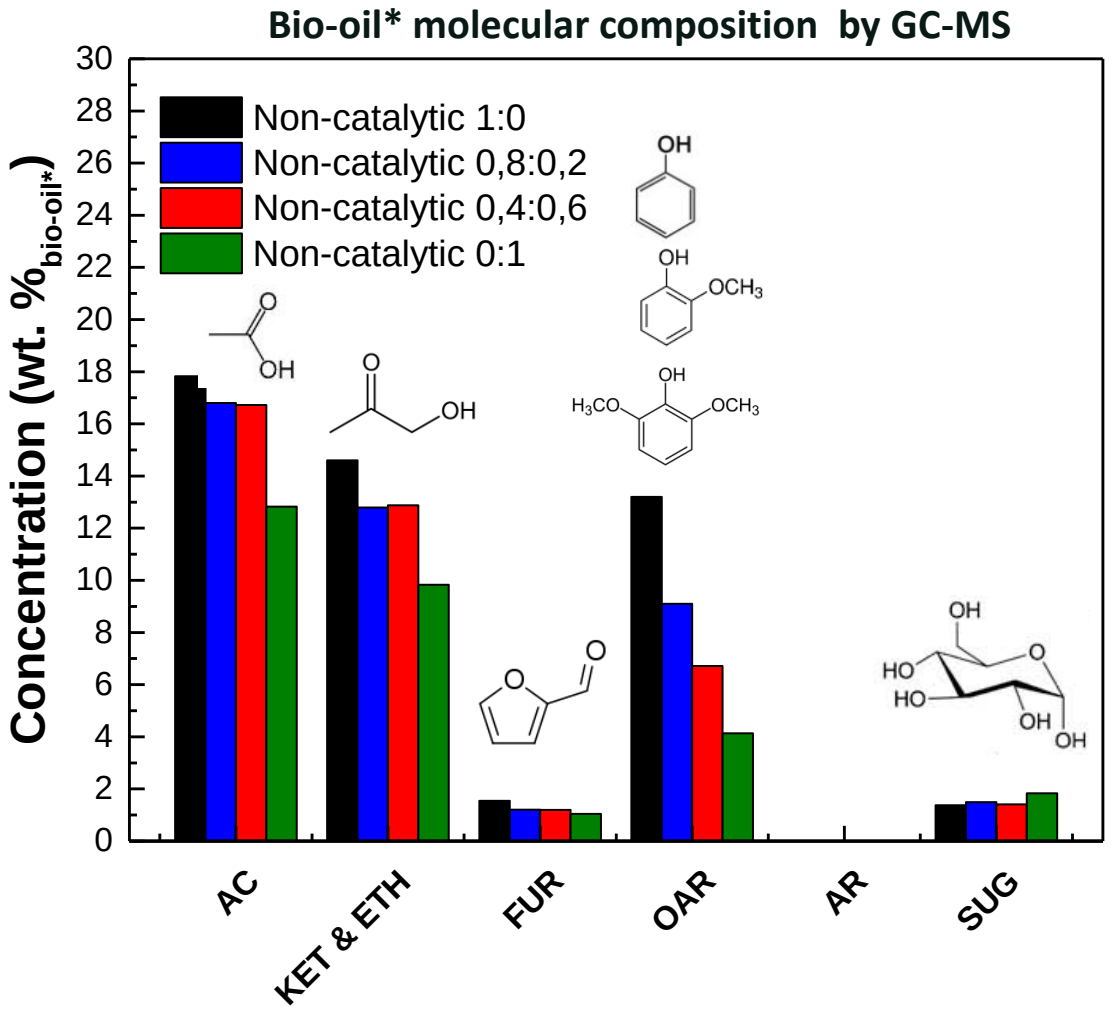
OFMSW & Garden pruning structural composition

Structural components	Composition (wt.%)	
	OFMSW	Garden pruning
Extractives	54,3	8,2
Cellulose	8,9	38,7
Hemicellulose	6,4	14,0
Lignin	15,3	29,1



Bio-oil molecular & elemental composition

Results



Higher OFMSW contents lead to:

- Decrease in Acids (AC) (17,8-12,8 wt.%), ketones and ethers (KET & ETH) (14,6-9,8 wt.%) and in oxygenated aromatics (OAR) (13,2-4,1 wt.%) .
- Decrease in quantifiable part of bio-oil* by GC-MS (From 50,8 to 30,0 wt.%).
- Lower oxygen content in bio-oil*.

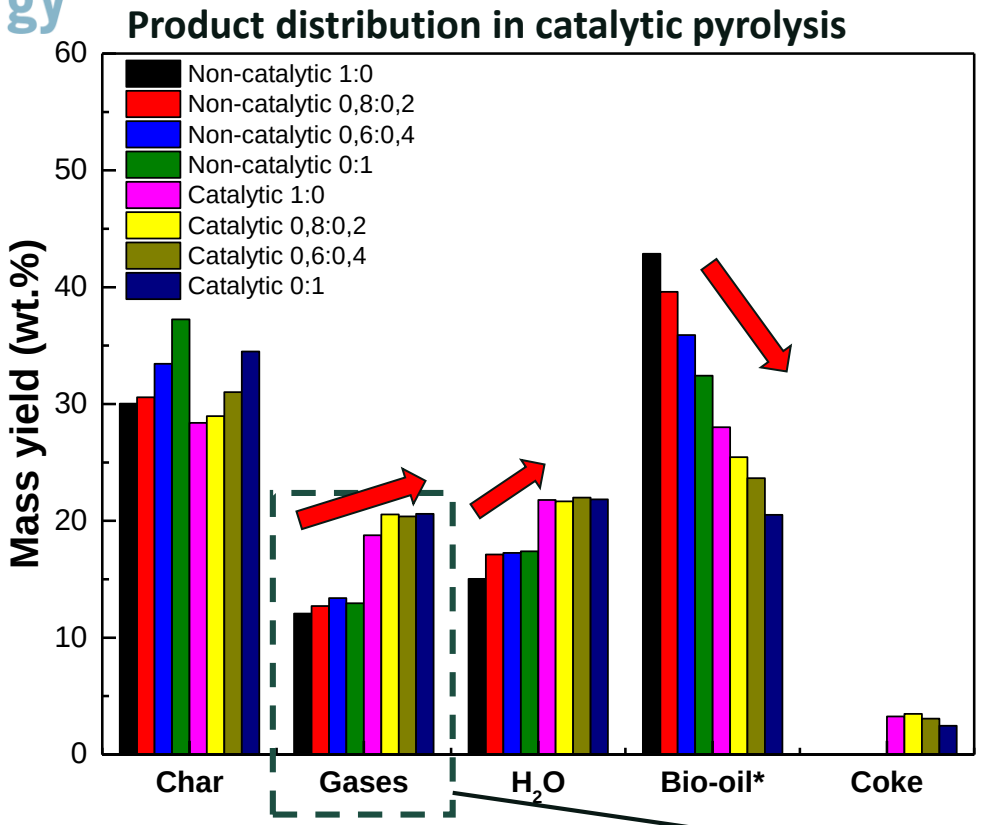
Bio-oil* elemental composition

Experiment	Elemental composition (wt.%bio-oil, db)				
	C	H	N	S	O
Non-catalytic 1:0	55,4	7,1	0,9	0,0	36,7
Non-catalytic 0,8:0,2	60,1	7,0	1,4	0,0	31,5
Non-catalytic 0,6:0,4	59,6	7,1	1,5	0,0	31,8
Non-catalytic 0:1	67,9	7,7	3,2	0,0	21,2

(- / + on the left; + / - on the right)

db: dry basis

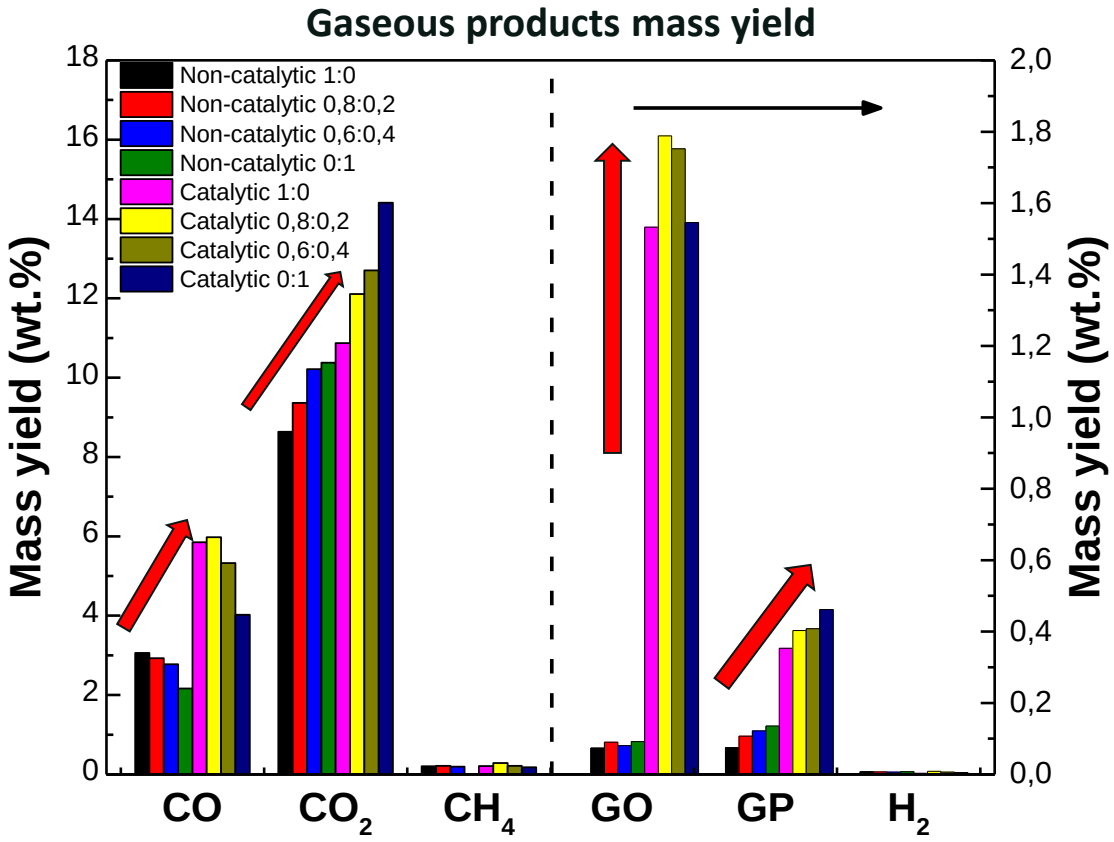
Effect of the addition of catalyst (n-ZSM-5)



- Increment in gas and water production and decrement in bio-oil* yield due to cracking and deoxygenation reactions

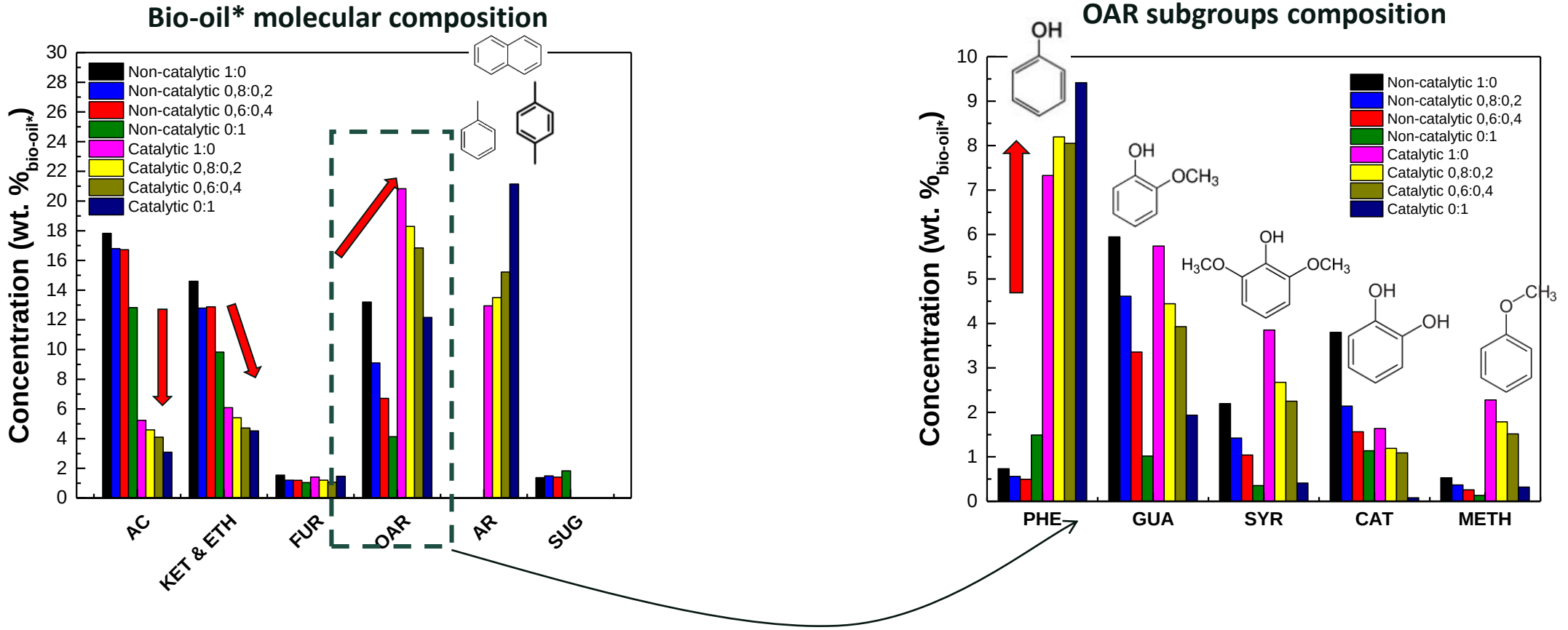
- Higher production of CO, and CO_2 because of decarbonilation and decarboxylation reactions

  - Higher content in light olefins and paraffins as a consequence of cracking reactions



Effect of the catalyst in the bio-oil composition

Results



- AC, KET&ETH decrease → Deoxygenation reactions
- SUG (Sugars) disappear and AR (Aromatic hydrocarbons) appear in high concentrations

- Increment in OAR concentration
  - Specially PHE (Phenols)

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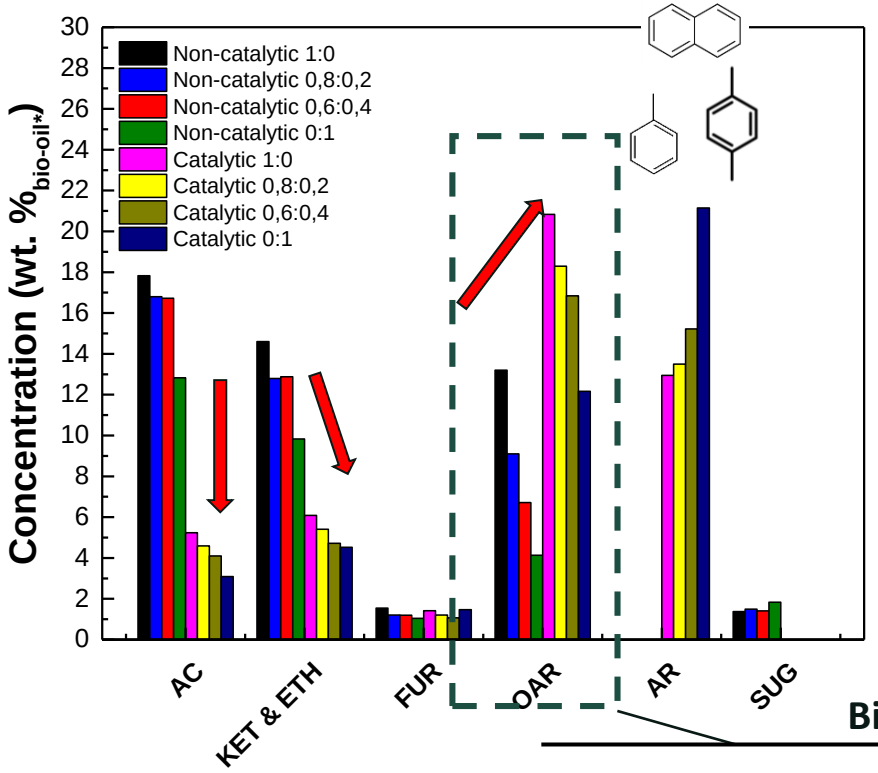
db: dry basis

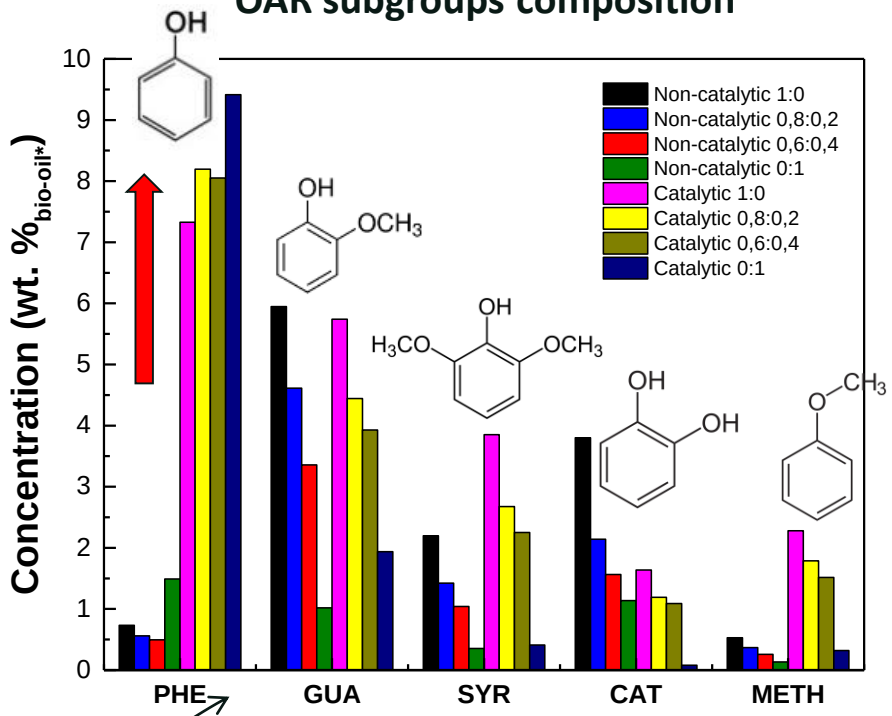
Effect of the catalyst in the bio-oil composition

Results

Bio-oil* molecular composition



OAR subgroups composition



Bio-oil* elemental composition

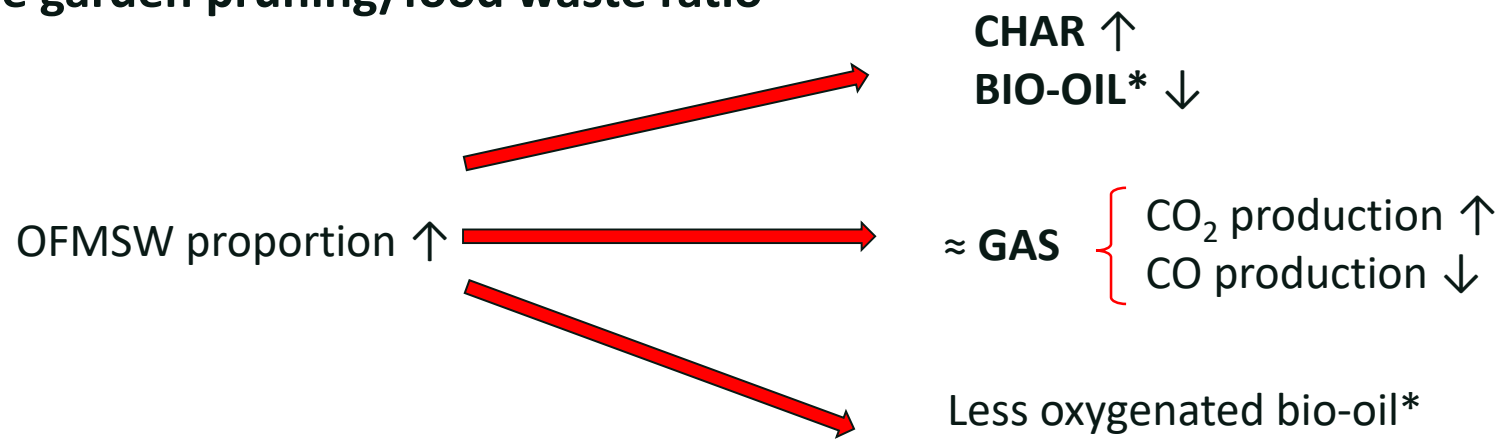
Experiment	Elemental composition (wt.%bio-oil, db)				
	C	H	N	S	O
Non-catalytic 1:0	55,4	7,1	0,9	0,0	36,7
Non-catalytic 0,8:0,2	60,1	7,0	1,4	0,0	31,5
Non-catalytic 0,6:0,4	59,6	7,1	1,5	0,0	31,8
Non-catalytic 0:1	67,9	7,7	3,2	0,0	21,2
Catalytic 1:0	69,4	8,3	1,7	0,0	20,6
Catalytic 0,8:0,2	69,4	8,8	2,4	0,0	19,5
Catalytic 0,6:0,4	74,8	8,9	2,0	0,0	14,4
Catalytic 0:1	74,5	9,8	3,0	0,0	12,7

(- / + : C; + / - : O)

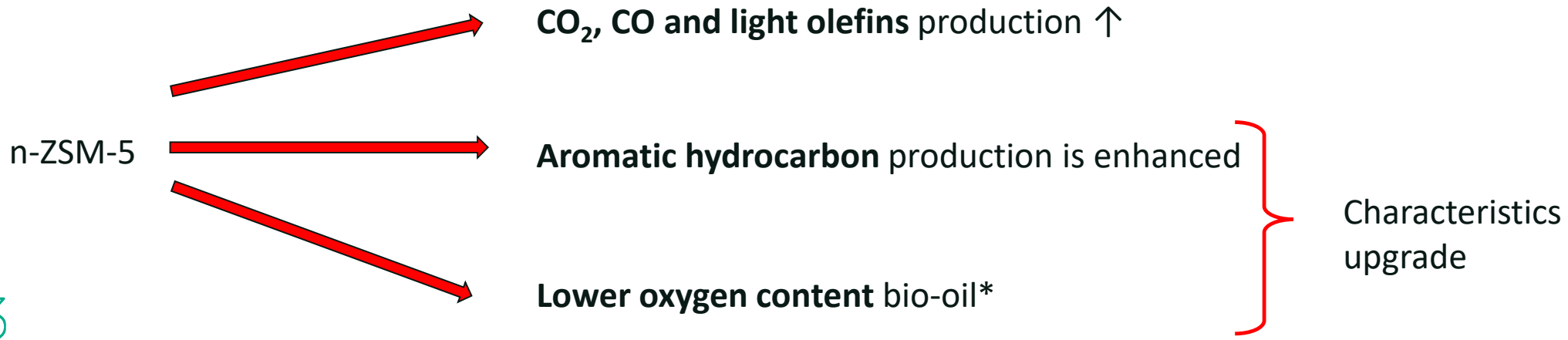
db: dry basis

Conclusions

- **Effect of the garden pruning/food waste ratio**



- **Effect of the addition of catalyst (n-ZSM-5):**



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Thank you for your attention !

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