Bio4A

Advanced Sustainable Biofuels for Aviation

Cultivating Camelina for sustainable aviation fuels in EU MED marginal land recovered with co-composted biochar and digestate: preliminary results

Bio-Char II: Production, Characterization and Application
September 15th-20th 2019,
Grand Hotel San Michele - Cetraro (Calabria), Italy

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RE-CORD

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BIO4A (Advanced Sustainable BIOfuels for Aviation) has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 789562.

RE-CORD - Renewable Energy Consortium for Research and Demonstration

RE·CORD

R&D ON BIOMASSES / BIOENERGY / BIOFUELS / BIOPRODUCTS

- ✓ **Public-private no-profit** research Institution
- ✓ **Members:** Univ. di Firenze (CREAR, Az. Agr. Montepaldi), Spike, Eta-Florence, Bioentech, GAL Start.

LABORATORY DEDICATED TO BIOMASS, BIOENERGY, BIOPRODUCTS

Biochar production
RE-CORD Facilities

Rotary Kiln

Slow pyrolysis of biomass & waste to fuels and products

- Solid (as fuel or amendment) + high T heat
- Integration in large-scale Advanced Biofuel supply chain
- IN=100 kg/h

CarbOn RE-CORD

Slow pyrolysis of biomass for charcoal and biochar making.

- Fixed bed, Open-top Oxidative Reactor (Autothermal)
- Designed and developed for small farmers
- Continuous operation.
- IN=50 kg/h. OUT=12kg/h (ηc = 24 wt.%)

Intermediate pyrolysis
Pilot Demo Unit

LIGNOCELLULOSIC RESIDUES

BIOCHAR

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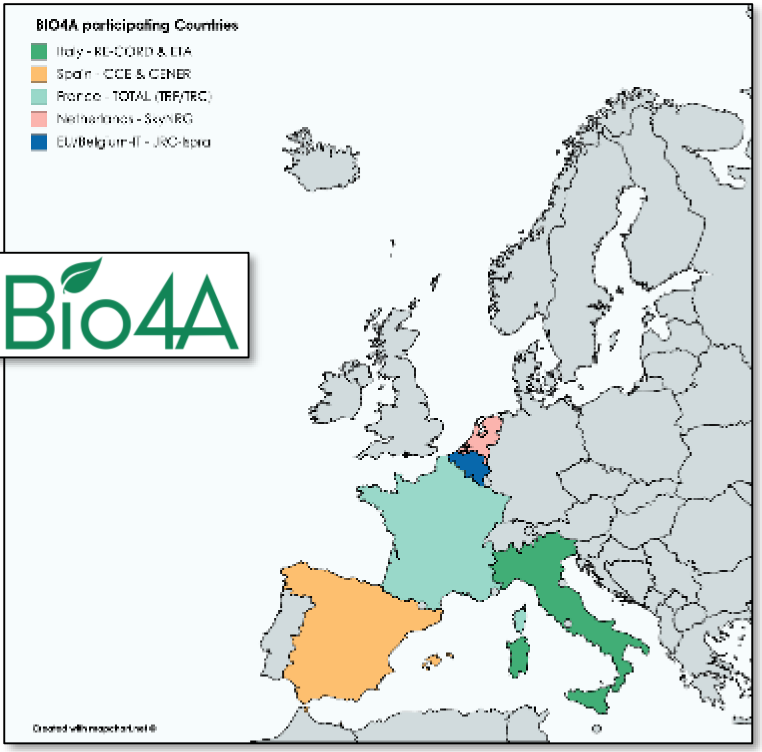
BIO4A Project
Specific challenge and main goals

Project Acronym: BIO4A   Project Number: 789562 Call: LCE-20-2016-2017   Topic: Aviation Biofuels

Project title: Advanced sustainable BIOfuels for Aviation



Specific Challenge

Accelerate the deployment of Aviation Biofuels, enabling commercial production. Supporting the accomplishment of pre-commercial plant(s) for advanced biofuels for aviation based on sustainable biomass feedstock.

Technological approach of the Project

Main goals:

1) To bring HEFA-based SAF to full commercial scale in new plant using sustainable lipids, e.g. UCO (new additional capacity);
2) To investigate alternative supply of sustainable feedstocks recovering EU MED marginal lands in combination with drought resistant crop production;
3) To test the entire chain and logistic at industrial scale, and assess environmental performances.

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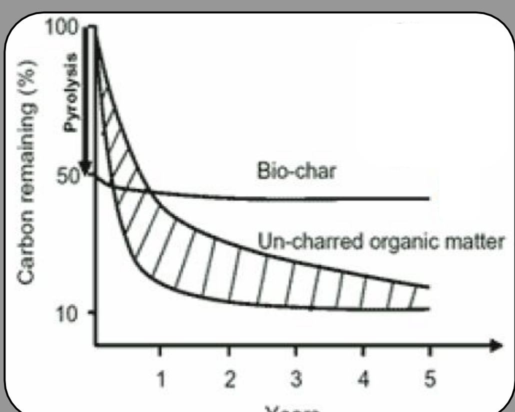
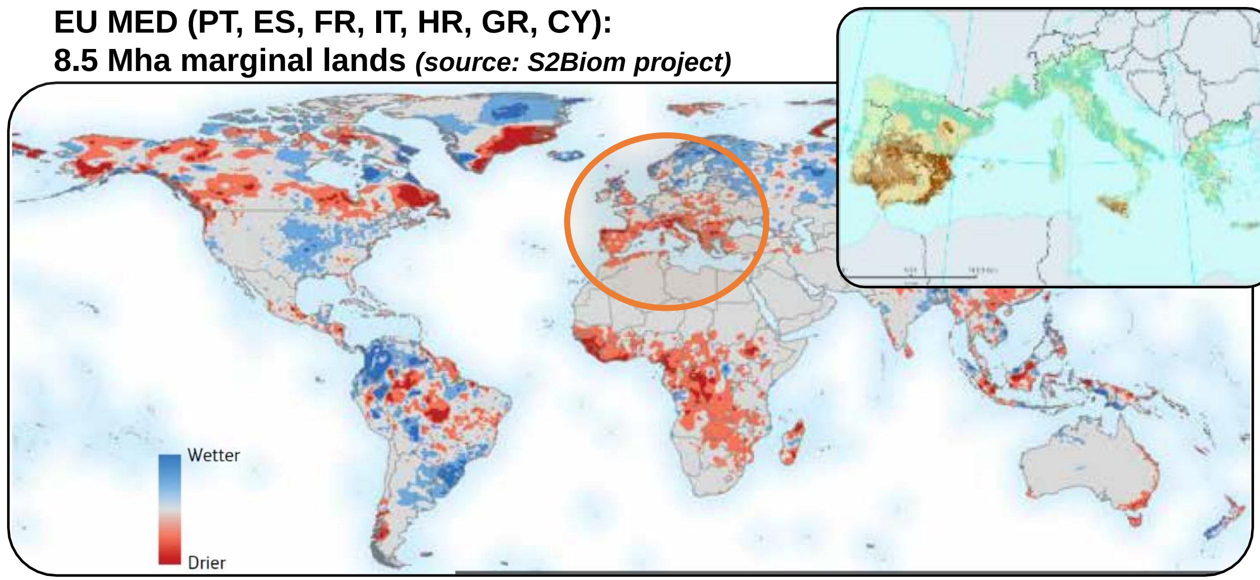
COM-BI for soil resistance and resilience and C sequestration

BIOCHAR sequesters C
(Climate Change Mitigation)



EU MED (PT, ES, FR, IT, HR, GR, CY):
8.5 Mha marginal lands ***(source: S2Biom project)***



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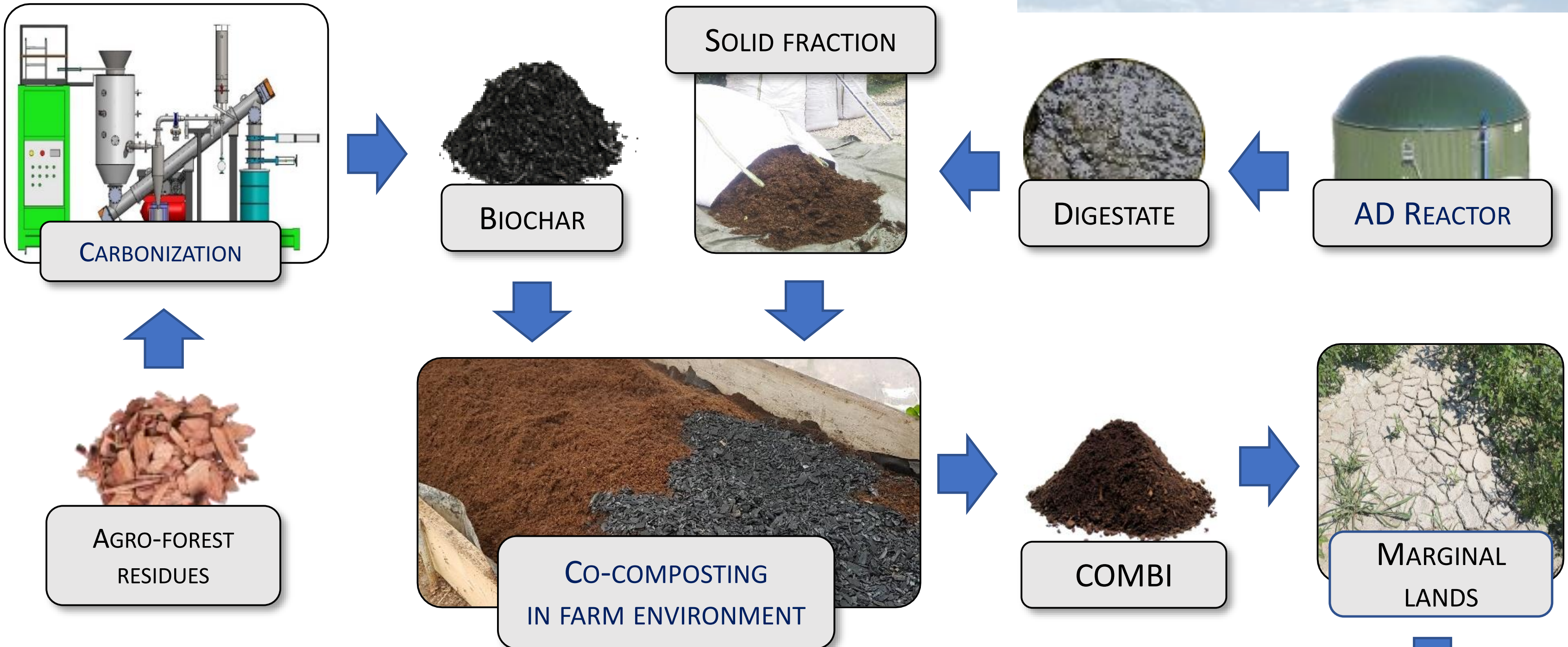
Sustainable lipid supply chain investigated in BIO4A project



COM-BI can be sustainably implemented in the driest marginal areas, fighting agricultural land abandonment, while increasing C sequestration.

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Key benefits of the co-composting process
State of the art

Key benefits of co-composting:

- biochar is charged with nutrients and a combination of living organisms;
- the compost quality and the efficiency of the process are improved:
  - time reduction and higher peak temperatures;
  - reduction of GHG emission, ammonia losses and odors).

Com-bi application to soils improves:

- biodiversity of the microflora, thanks to the characteristics of compost and the suitable environment of biochar for microorganisms;
- plant availability of nutrients, reducing leaching;
- plant availability of water, thanks mainly to the water holding capacity of biochar;
- soil structure, pH and aeration.

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Design of the experiment
Re-Cord and Camelina Company activities





COMBI production in field condition		Delivery	Locations	Field trials
Batch 1	Summer season (Aug-Oct 2018)	CD1, CB1, CB2, CB3	L1: La Canaleja Madrid, Spain	Started in November 2018
Batch 2	Winter season (Dec-Feb 2018/19)	CD2, CB4, CB5, CB6	L2: Entresierras Ciudad Real, Spain	Started in February 2019

Feedstock and product characterization

- Woodchips
- Biochar → EBC
- Solid fraction of digestate
- COMBI products → ECN-QAS

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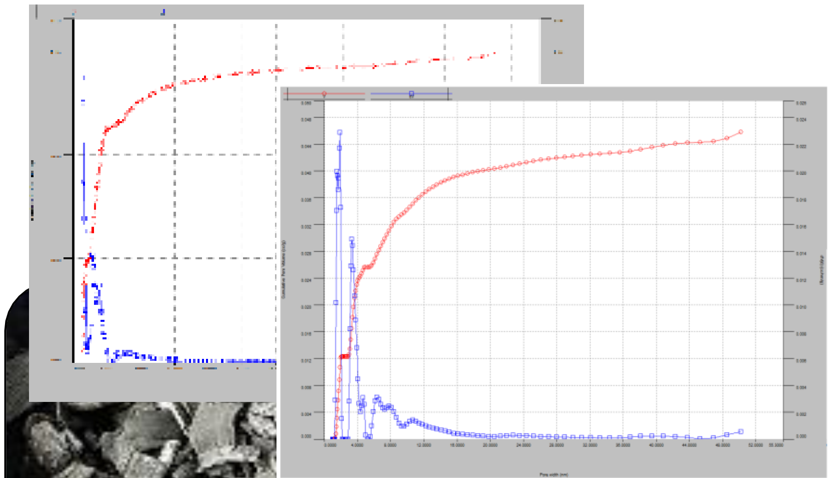
Biochar used for COMBI production Characterization

Parameter	U.M.	Batch 1	Batch 2	Method
Feedstock	-	chestnut	chestnut	-
Bulk density	kg m^{-3}	146	280	EN 15103
pH	-	7,97		ISO 10390
Water content	% w/w d.b.	5	4,4	EN 14774-2
Volatile matter	% w/w d.b.	14,5	13,2	EN 15148
Fixed carbon	% w/w d.b.	80,8	83,0	EN 1860-2
Total ash	% w/w d.b.	4,7	3,8	EN 14775
Total C	% w/w d.b.	86,2	87,5	EN 15104
Total N	% w/w d.b.	0,6	0,8	EN 15104
Total H	% w/w d.b.	2,1	2,2	EN 15104
Total S	% w/w d.b.	0,04	0,02	EN 15104
Total P	mg kg^{-1} d.b.	b.d.l.	b.d.l.	EN 15290
Total K	mg kg^{-1} d.b.	5259	4027	EN 15290
Total Mg	mg kg^{-1} d.b.	851	819	EN 15290
Total Ca	mg kg^{-1} d.b.	9073	8043	EN 15290
Molar H/C	-	0,29	0,33	
Specific surface area	m^2 g^{-1}	216	127	ASTM D6556
Heavy metals, metalloids and other elements: Pb	mg kg^{-1} d.b.	b.d.l.	b.d.l.	EN 15290
Cd	mg kg^{-1} d.b.	b.d.l.	b.d.l.	EN 15290
Cr	mg kg^{-1} d.b.	b.d.l.	4	EN 15290
Cu	mg kg^{-1} d.b.	b.d.l.	b.d.l.	EN 15290
Ni	mg kg^{-1} d.b.	b.d.l.	b.d.l.	EN 15290
Zn	mg kg^{-1} d.b.	b.d.l.	74	EN 15290

Operating condition	Slow oxidative pyrolysis
Inlet feed	50 kg $_{w.b.}$ h^{-1}
Maximum process temperature	550° C
Residence time	3 h



Brunauer–Emmett–Teller (BET) theory and density functional theory (DFT)

pores width ranges from about 1 nm to about 10 nm.

Micro and Mesopore distribution

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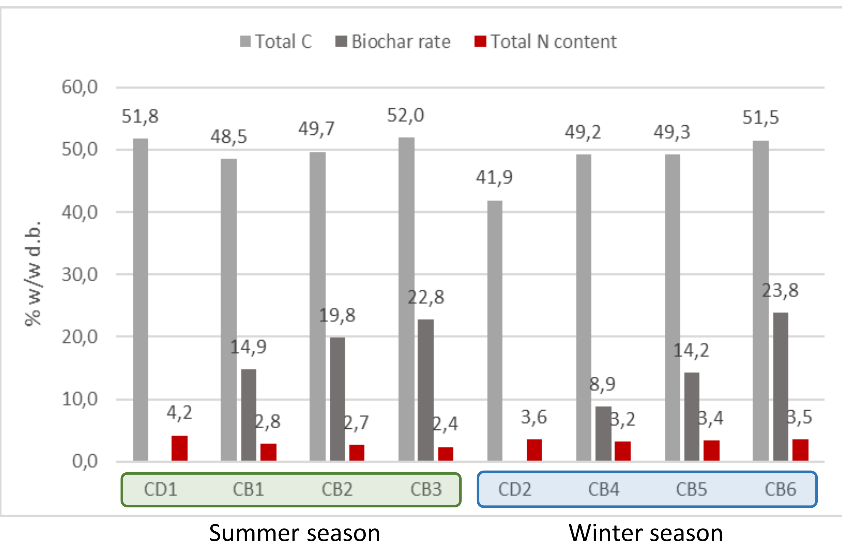
COMBI production test
Final biochar rate in the product

		Summer season				Winter season			
Parameter	**U.M.**	**CD1**	**CB1**	**CB2**	**CB3**	**CD2**	**CB4**	**CB5**	**CB6**
Starting biochar rate	% w/w w.b.	0,0	10,0	15,0	20,0	0,0	10,0	15,0	20,0
Final biochar rate	% w/w d.b.	0,0	14,9	19,8	22,8	0,0	8,9	14,2	23,8
Total C	% w/w d.b.	51,8	48,5	49,7	52,0	41,9	49,2	49,3	51,5
Total N	% w/w d.b.	4,19	2,84	2,69	2,41	3,62	3,21	3,38	3,53
Final C/N ratio	%	9,5	16,0	16,8	21,1	5,9	8,9	8,8	9,7

Production tests in farm environment

It is difficult, producing COMBI in farm environment, to predict the **final biochar rate by weight, dry basis**: mainly due to the uncertainty of the efficiency of the process in farm environment (influenced by climate and digestate properties seasonal variation), lasted for 60 days.




Production test in farm environment at Scandicci (Florence, Italy).

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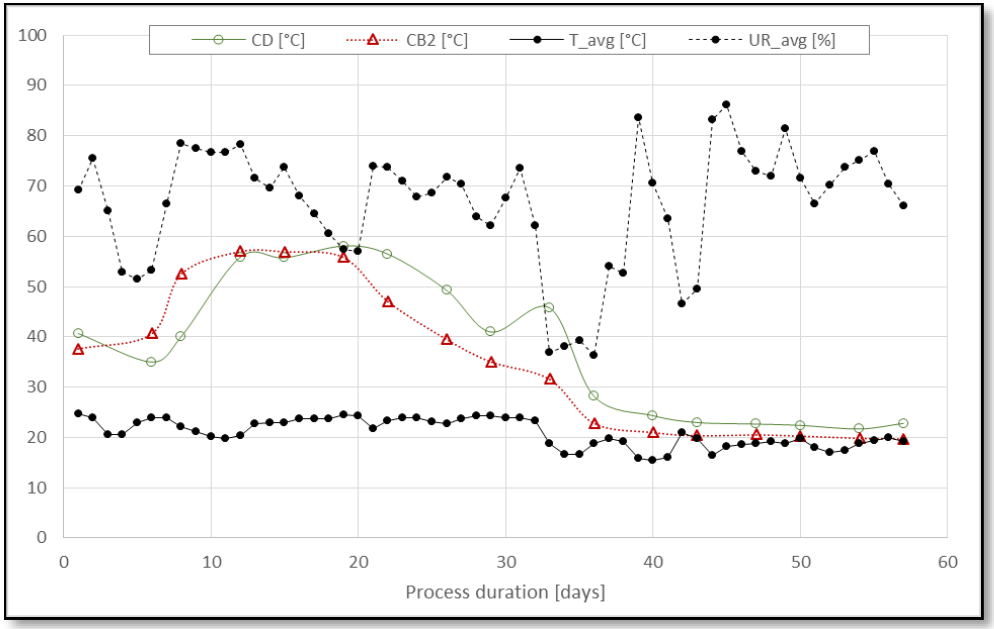
COM-BI production test
Process analysis

Differences in Summer and Winter production tests

In Summer the process started easily, reaching also sanitizing temperature in the process and a higher organic matter devolatilization for all the blends.



- COMBI CB2 (red) had lower processing time of about 4 days less respect to control CD1 (green).
- Similar peak temperatures.

In Winter, no processing time reduction for COMBI blends.
A heating system is needed to guarantee a correct sanitization phase (following ECN-QAS).

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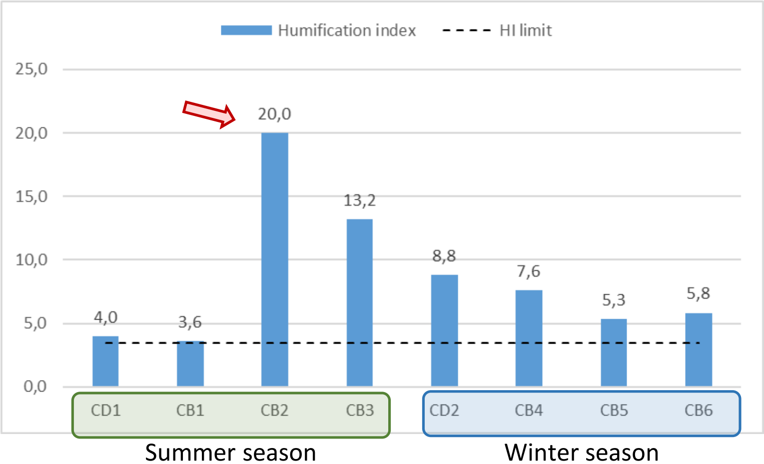
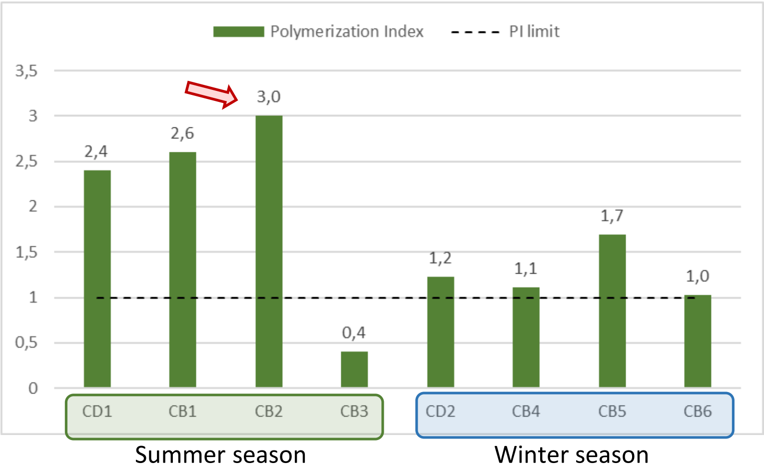
COMBI production test
Product stabilization and maturation (1)

Parameter	U.M.	Criteria	Summer season CD1	Summer season CB1	Summer season CB2	Summer season CB3	Winter season CD2	Winter season CB4	Winter season CB5	Winter season CB6
PDRI	mg O_2 kg_{OM}^{-1} h^{-1}	< 480	< 300	350	< 200	< 200	280	260	310	310
Humification Index (HI)	%	> 3.5 %	4.0	3.6	20.0	13.2	8,8	7,6	5,3	5,8
Polymerization index (PI)	%	> 1.0 %	2.4	2.6	3.0	0.4	1,2	1,1	1,7	1,0

Product stabilization and quality

- **PDRIs show a good product stabilization** with all values under the ECN-QAS limit for compost used as growing media, fluctuating from <200 to 350 mg O_2 kg_{OM}^{-1} h^{-1}.
- **Humic Acids (HA) and Fulvic Acids (FA) content are representative of the humification degree.** A higher degree of humic substances correspond to a more efficient stabilization of the OM during composting.
- The two main indexes used in this study to evaluate the humification level of the products, following Roletto et al, were the Humification Index (HI, representing the ratio between HA and organic carbon contents) and the Polymerization Index (PI, representing the ratio between HA and FA).





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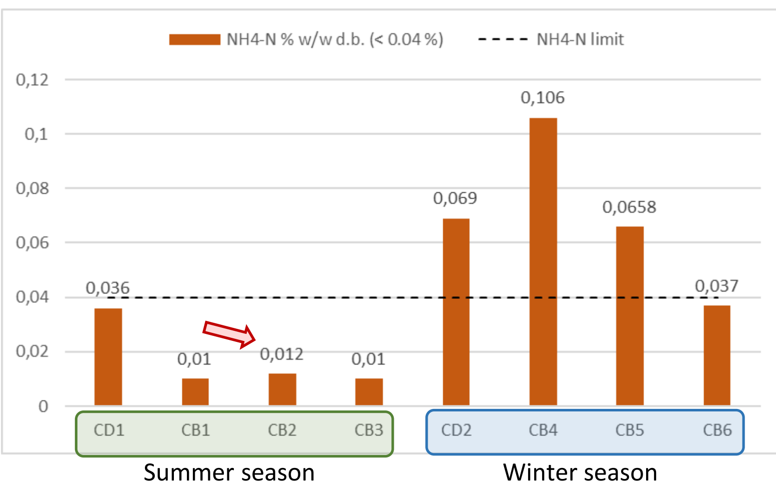
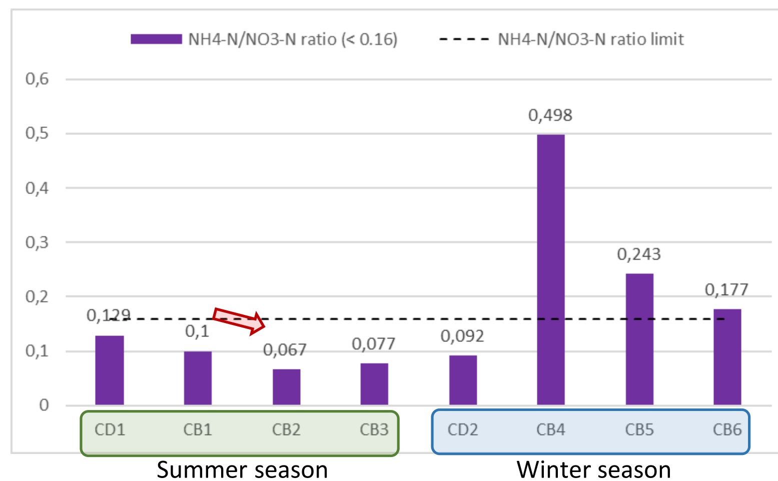
COMBI production test
Product stabilization and maturation (2)

Parameter	U.M.	Criteria	Summer season				Winter season			
			CD1	CB1	CB2	CB3	CD2	CB4	CB5	CB6
NH_4-N	% w/w d.b.	< 0.04 %	0.036	0.010	0.012	0.010	0.069	0.106	0.066	0.037
NH_4-N/NO_3-N ratio	-	< 0.16	0.129	0.100	0.067	0.077	0.092	0.498	0.243	0.177

Product stabilization and quality

- **A high level of NH4-N forms is an indication of a low stabilization for the OM.** NH4-N form is prevailing during the mineralization processes of the OM, typical of the bio-oxidation phase. On the other hand, since nitrification of ammonium mostly occurs after the thermophilic phase, **NO3-N concentration can be retained as a good indicator of compost stabilization.**
- The NH4-N limit of 0.04% w/w d.b. is proposed by Zucconi and de Bertoldi or mature compost (though from the organic fraction of municipal solid wastes)
- Bernal et al. proposed a limit of 0.16 to the NH4-N/NO3-N index to define a compost sufficiently mature.





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COMBI production test
Conclusions

- Difficulties, in farm environment, to predict the final biochar rate of the product.
- Biochar addition during the Summer season improved the co-composting process efficiency (accelerating also the process) and product quality in terms of stabilization and maturation of the compost.
- During Winter, when COMBI is directly produced in field conditions, the process needs a more complex system to guarantee the quality of the process (heating system, moisture adjustment, etc.).

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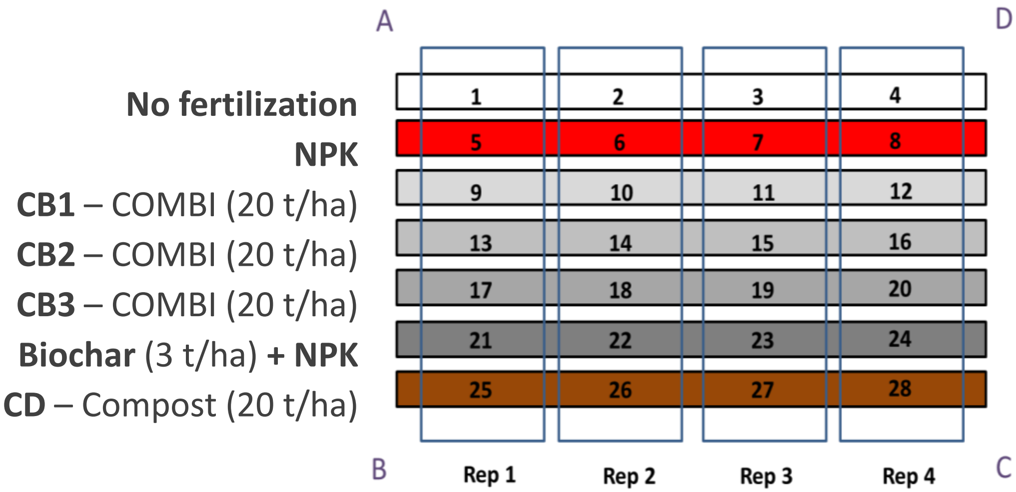
COMBI production test
Field trials



Analysis on-going: **soil, biomass yield, grain yield, oil content.**

PRELIMINARY RESULTS

<u>Location 1</u> showed low cumulative pluviometry (86.2 mm) from germination to harvest:

- Control and NPK yield approx. 0,
- Combi and Biochar maximum grain yield were higher than Compost.

<u>Location 2</u> showed adequate cumulative pluviometry (109.6 mm) from germination to harvest:

- Compost, Combi and Biochar expressed highest maximum grain yield compared to control and NPK (+40/50%).

Notes: All replications showed great variability, statistically consolidated data necessary.

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Project Partners

RE-CORD · TOTAL · SkyNRG · etaflorence renewableenergies · Camelina Company | España · CENER · European Commission

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Biochar characteristics

Granulometry	***>63 mm %wt***	**0.0**
	>45 mm %wt	6.2
	>31.5 mm %wt	5.8
	>16 mm %wt	31.3
	>8 mm %wt	29.0
	>3.15 mm %wt	17.9
	<3.15 mm %wt	9.8
Granulometry	*>5 mm %wt*	86.6
	>2 mm %wt	9.7
	>0.5 mm %wt	3.0
	<0.5 mm %wt	0.7

PAHs	ppm db
Naphthalene	0,58
Acenaphthylene	0,00
Acenaphthene	0,00
Fluorene	0,00
Phenanthrene	0,14
Anthracene	0,04
Fluoranthene	0,00
Pyrene	0,00
Benz(a)anthracene	0,12
Chrysene	0,00
Benzo(b)fluoranthene	0,14
Benzo(k)fluoranthene	0,08
Benzo(a)pyrene	0,00
Dibenz(a,h)anthracene	0,01
Benzo(ghi)perylene	0,01
Indeno(1,2,3-cd)pyrene	0,01
Total *(mg/kg)*	**1,14**

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Products characterization following EBC standards

Products analysis results

			Summer season				Winter season			
Parameter	**U.M.**	**Criteria**	**CD1**	**CB1**	**CB2**	**CB3**	**CD2**	**CB4**	**CB5**	**CB6**
Organic matter	% w/w d.b.	≥ 15	75,47	81,34	81,49	82,03	83,17	85,33	86,53	87,33
Liming value	% w/w d.b.	declaration	2,67	2,23	1,74	3,36	3,51	2,07	2,23	2,28
Total N	% w/w d.b.	declaration	4,19	2,84	2,69	2,41	3,62	3,21	3,38	3,53
Total P	mg/kg	declaration	11353	7599	2826	2873	11983	9913	8792	9169
Total K	mg/kg	declaration	25568	22215	17405	16656	18322	16254	15852	15229
Total Mg	mg/kg	declaration	7737	6917	4813	5452	9159	8446	7468	7596
Dry matter	% w/w w.b.	declaration	48,2	51,5	50,3	48,0	32,4	29,3	35,5	33,8
Electrical conductivity	$mS\ m^{-1}$	declaration	3,57	2,47	2,85	2,41	0,16	0,06	0,06	0,09
pH value		declaration	8,2	8,6	8,2	8,3	8,5	8,0	8,2	8,5
Aerobic biological activity	mg O2/kg_SV h	declaration	270	350	<200	<200	280	260	310	310
Salmonellae		absent in 25 g d.b.	absent	absent	absent	absent	absence	absence	absence	absence
Inorganic pollutants	$mg\ kg^{-1}$ d.b.	Pb < 130	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.
		Cd < 1.3	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.
		Cr < 60	20	7	5	6	b.d.l.	b.d.l.	b.d.l.	b.d.l.
		Cu < 300 *	37	24	21	24	b.d.l.	b.d.l.	b.d.l.	b.d.l.
		Ni < 40	5	1,2	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.
		Hg < 0.45	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
		Zn < 600 *	196	153	143	142	180	156	138	152

- The compost products obtained met main reference limits of ECN-QAS (European Compost Network Quality Assurance Schemes)

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