

**11:30-13:00 | BREAK-OUT SESSIONS**

 **Silver Room – Sea2land**

 **Studio 202 – Novafert**

# 11:30-13:00 | BREAK-OUT SESSION

## Silver Room – Sea2land



**11:30-12:00**

*Agronomic performance and emission monitoring of circular fertilisers*

Mette Thomsen (NIBIO)

**12:00-12:30**

*Production technologies for circular fertilisers*

Bruno Iñarra Chastagnol (AZTI)

Nagore Guerra Gorostegi (NEIKER)

**12:30-13:00**

*Quality & safety assessment of circular fertilisers*

Çağrı Akyol (UGent)



## WP 5 Evaluation of agronomic and environmental performance



Origin	Side-stream
Baltic Sea	Fish processing by-products
Cantabrian Sea	Tuna cooking process water; Fish viscera
	Coproducts of biorefinery of viscera and tuna cooking water
North Sea	Fish sludge
Atlantic Sea	Fishery by-products (head, bone & viscera)
Mediterranean	Aquaculture sludge (marine)
Freshwater	Sludge from freshwater aquaculture

*Foliar fertilizer, Organic fertilizer, Plant Biostimulant, Soil improver, Liming agent*



# WP5 Evaluation of **Biobased fertilisers (BBFs)** - agronomic - and environmental performance.



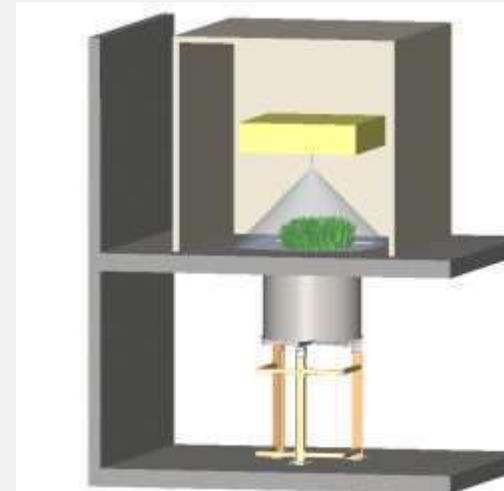
Task 5.1 Pot experiment



5.2 Field experiment



5.3 Modelling



5.4 Ecotron experiment



## Pot experiment.

### WP 5.1 Pot experiments to assess NPK availability of bio-based fertilizers

Lead: METK & FiBI

**Objective of the Pot Experiment:** Bio-based fertilisers (BBFs) developed in WP3 and WP4 was screened in greenhouse conditions to determine the fraction of N, P and K in bio-based fertilisers the plant can take up

**BBFs Tested:** 16 BBFs tested for N uptake, 9 for P uptake and 6 for K uptake.

Treatment code	NUE%	
	Mean±SD	
Fert. control	63.35±11.35	a
BP	3.91±1.57	fg
VER	1.30±0.77	g
FER1	35.64±1.06	c
FER2	33.37±0.75	cd
<b>FER3</b>	<b>43.03±2.47</b>	<b>bc</b>
FER4	41.57±6.81	bc
FER5	49.99±1.84	b
UNI1	10.56±3.97	efg
UNI2	5.67±1.89	fg
UNI3	10.56±2.58	efg
<b>FSP</b>	<b>43.91±1.90</b>	<b>bc</b>
FMP	15.26±2.27	ef
<b>CAT1</b>	<b>22.14±3.15</b>	<b>de</b>
CAT2	36.40±1.86	c
OA1	42.08±3.78	bc
OA2	6.78±1.34	fg
Prob > F	<.0001	

# Pot experiment

All selected BBFs demonstrated varying degrees of nutrient availability compared to mineral fertilizers, with some showing promising results in N, P and K uptake.

Based on the pot experiment results, the most promising BBFs (**FER3**, **FSP**, and **CAT1**) were selected for field trials.



Liina Edesi



## Total Nitrogen (TN) in selected BBFs

Area	Code	Dry matter/ %	TN/% DW
Adriatic Sea (Local Belgium)	UNI1	42,1	11,45
Baltic Sea (Local Estonia)	BP	90,6	2,90
Cantabrian Sea	FER3	34,5	15,40
North Sea	FSP	94,4	6,55
North Sea (Local Norway- Mix)	FMP	94,5	10,34
Atlantic Sea	CAT1	98,1	7,77



# Pot Experiment. Mineral fertiliser equivalent in BBFs

Area	Code	N-MFE %		P-MFE%		K-MFE%	
		Mean		Mean		Mean	
Conventional	Control	100	a	100	a	100	a
Baltic sea (Local Estonia)	BP	5,7 <sup>6</sup>	fg	60	d	50,1	b
Cantabrian sea	FER3	73,3	bc	60,2	d	60,6	b
Adriatic sea (local Belgium)	UNI1	15,5	efg				
North sea	FSP	64,5	cd	39,1	e	20,7	d
North sea (Local Norway)	FMP Fish + bone- meal Mix	22,4	ef	80,3	b	67,9	b
Atlantic sea	CAT1	32,5	e	83,6	ab		



# Pot Experiment. Nutrient Use Efficiency in BBFs

Area	Code	NUE %		PUE%		KUE%	
		Mean		Mean		Mean	
<b>Conventional</b>	Control	63	a	53,6	a	81,0	a
<b>Baltic sea</b> (Local Estonia)	BP	3,9	fg	32,2	d	40,5	b
<b>Cantabrian sea</b>	FER3	43,0	bc	32,2	d	49,1	b
<b>Adriatic sea</b> (local Belgium)	UNI1	10,6	efg				
<b>North sea</b>	FSP	43,9	cd	21,0	e	16,7	d
<b>North sea</b> (Local Norway)	FMP	15,3	ef	43,0	b	55,0	b
<b>Atlantic sea</b>	CAT1	22,1	e	44,8	ab		

NUE = Nitrogen use efficiency. % of N recovered by plants from the applied fertilizer

### **WP 5.1 Field experiments. Validation of predicted effects from the pot experiment**

**Lead: NIBIO**

**Objective of the Field Experiment:** Three common + one locally chosen BBF was tested in field experiments. Countries performing field tests were Norway, Estonia, Belgium, Spain and France. Crop performance and yield components as well as effects on soil (e.g. liming effect), NUE and MFE.

**Common crop:** Broccoli. **Residual crop:** Winter wheat/Spain: onion/lettuce



# Field Experiment – Total biomass (t DW ha<sup>-1</sup>)

	Belgium	Estonia	France	Norway	Spain 23	Spain 24
Control fertiliser	Chicken manure	Mineral fertiliser	Commercial organic	8K, Grønn gjødsel	Mineral fertiliser	Mineral fertiliser
POS CON	3.0 a	9.4 a	1.0 ab	2.5 c	3.1 ab	5.3 ab
NEG CON	2.7 c	6.4 c	0.6 b	3.5 bc	2.1 b	1.8 d
CAT1	3.5 a	8.3 abc	1.0 ab	5.3 ab	3.2 a	3.5 c
FER3	3.6 a	8.5 ab	1.5 a	6.2 a	2.9 ab	5.6 a*
FSP	3.1 a	7.6 abc	1.3 ab	4.3 ab	3.4 a	4.1 bc

\* FER3 + mineral fertiliser

Astrid Solvåg Nesse

## Results BBF trials – Commercial yield (t FW ha<sup>-1</sup>)

	Belgium	Estonia	France	Norway	Spain 23	Spain 24
Control fertiliser	Chicken manure	Mineral fertiliser	Commercial organic	8K, Grønn gjødsel	Mineral fertiliser	Mineral fertiliser
POS CON	5.1	14.1	1.3 ab	5.6 ab	5.0 a	1.9 c
NEG CON	5.5	8.9	0.1 b	4.1 b	1.5 c	0
CAT1	6.5	11.9	1.0 ab	10.0 ab	3.1 ab	0.2 bc
FER3	6.4	14.7	2.1 a	13.2 a	4.0 ab	1.9 a
FSP	4.6	9.8	1.2 ab	7.4 ab	2.9 ab	0.5 bc



# Field Experiment



August 1.



August 15.



## Results BBF trials – Nitrogen uptake (kg /ha)

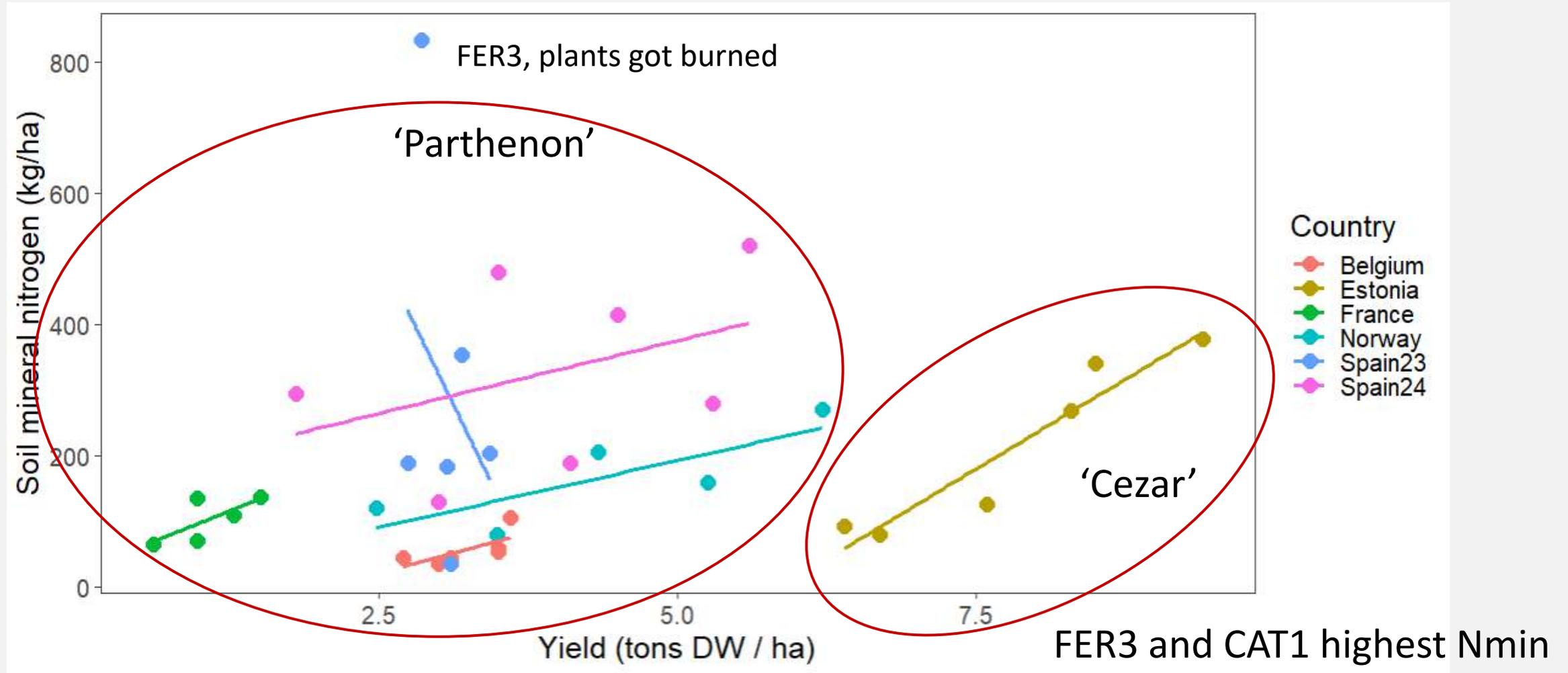
120 kg N / ha added

	Estonia	France	Norway	Spain 23	Spain 24
Control fertiliser	Mineral fertiliser	Commercial organic	8K, Grønn gjødsel	Mineral fertiliser	Mineral fertiliser
POS CON	315 a	3 b	39 b	119 a	103 ab
NEG CON	152 d	20 b	43 b	69 b	27 e
CAT1	254 abc	30 b	82 ab	139 a	73 cd
FER3	281 ab	48 a	81 ab	130 a	118 a
FSP	202 cd	45 a	56 ab	124 a	65 d



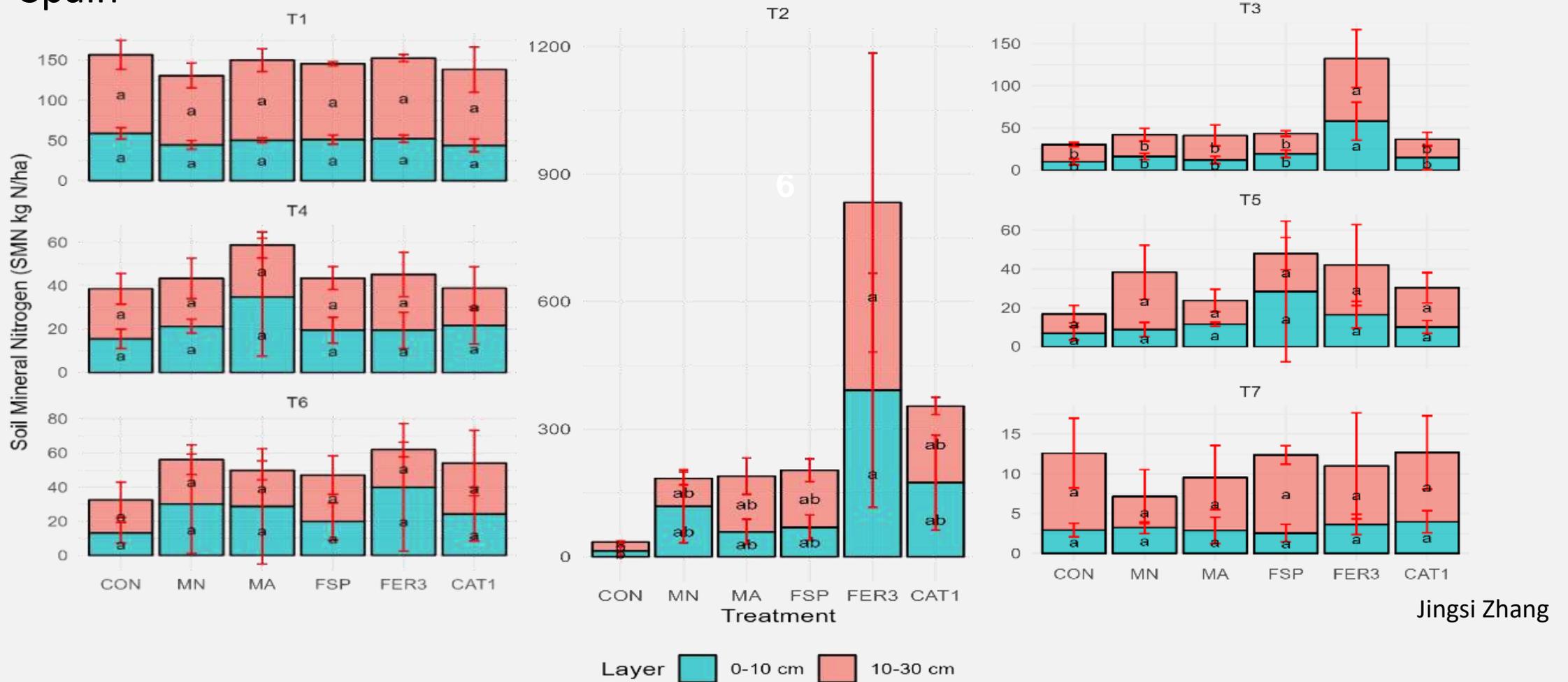
- Generally higher yield in fields previously fertilised with BBFs than mineral fertiliser (MF)
- Tendency towards higher protein content as well in winter wheat (not statistically significant)
- Norway: Similar performance of the tested BBFs and the organic control

# Soil mineral nitrogen (1wk after fertilisation) - yield at harvest



# Nitrogen mineralization

## Spain

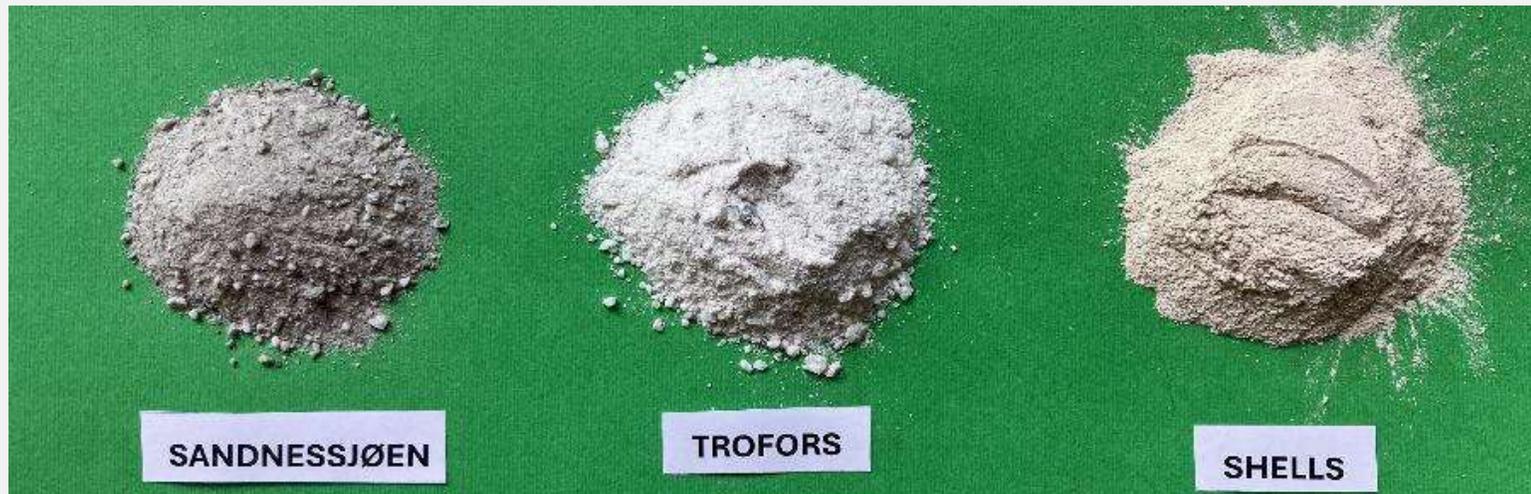


Jingsi Zhang

$E_1 < 1$ . Corrective power lower than  $\text{CaCO}_3$  and  $\text{CaO}$ . After 30 days

	$E_1 \text{ CaCO}_3$	$E_1 \text{ CaO}$
Sandnessjøen	0.25	0.17
Trofors	0.43	0.29
Shells < 1mm	0.82	0.55
Shells > 1mm	0.48	0.32

- Grinding size important for short-term efficacy
- No differences in field test



## Task 5.3 Simulation modelling of agronomic performance and environmental Impacts

Lead: **NEIKER.**

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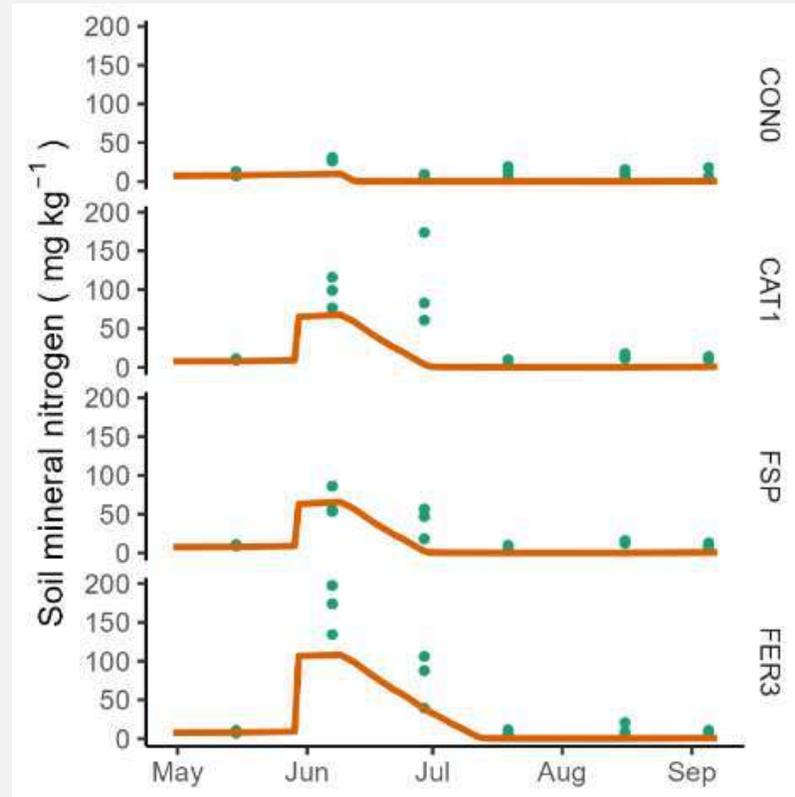
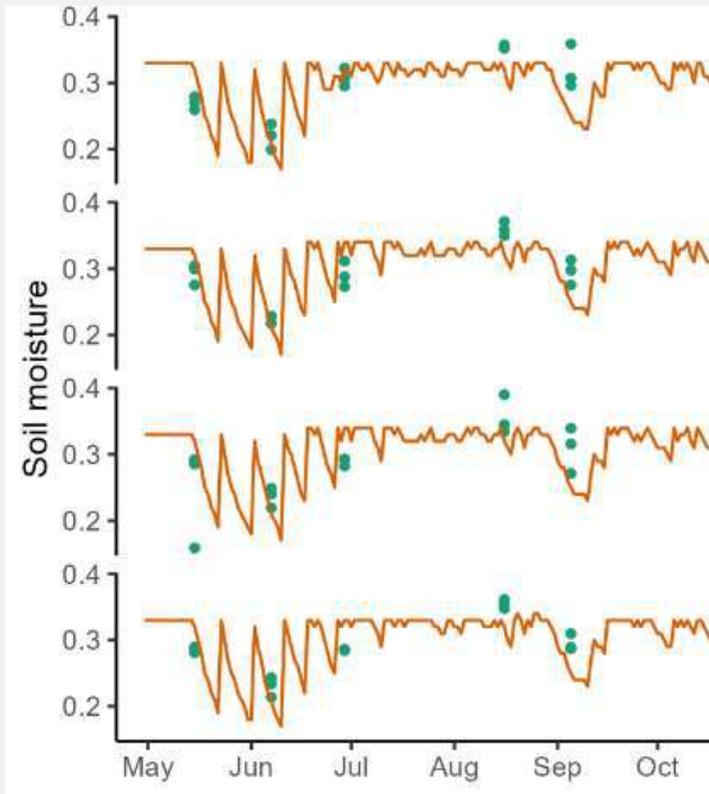
Two crop models, DSSAT and DNDC, has been tested using the available data from the lab and field trials.

Models were run for average weather conditions as well as for more extreme years of climatic conditions across Europe.

Giving an overview of both expected values and temporal and spatial variability of fertiliser performance.

In addition, the model will give first insight about possible effects under predicted climate change.

## Example of simulated and observed soil water content and mineral nitrogen, Norway 2023



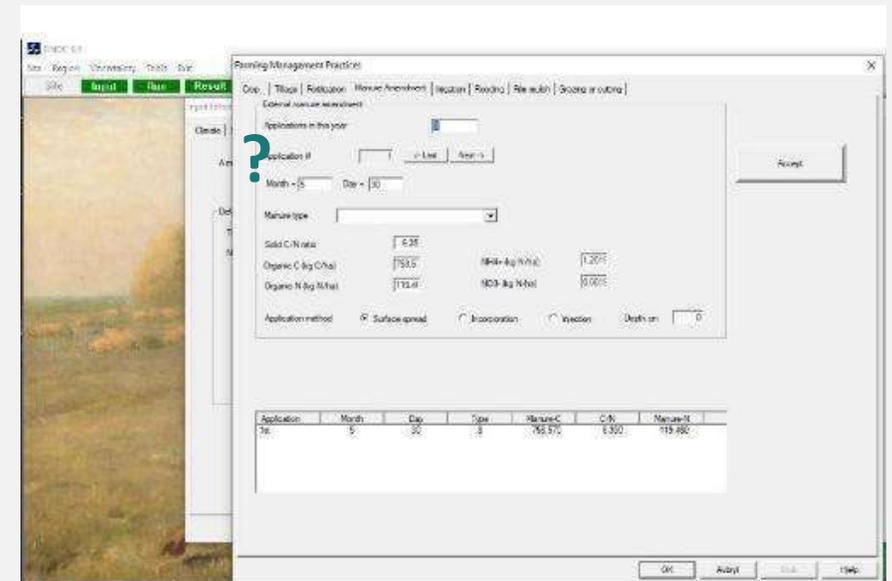
Very good performance of the calibrated model with respect to crop yield.

$R^2 = 0.84$  and

$RSR = 0.41$

Iva Zivanovic

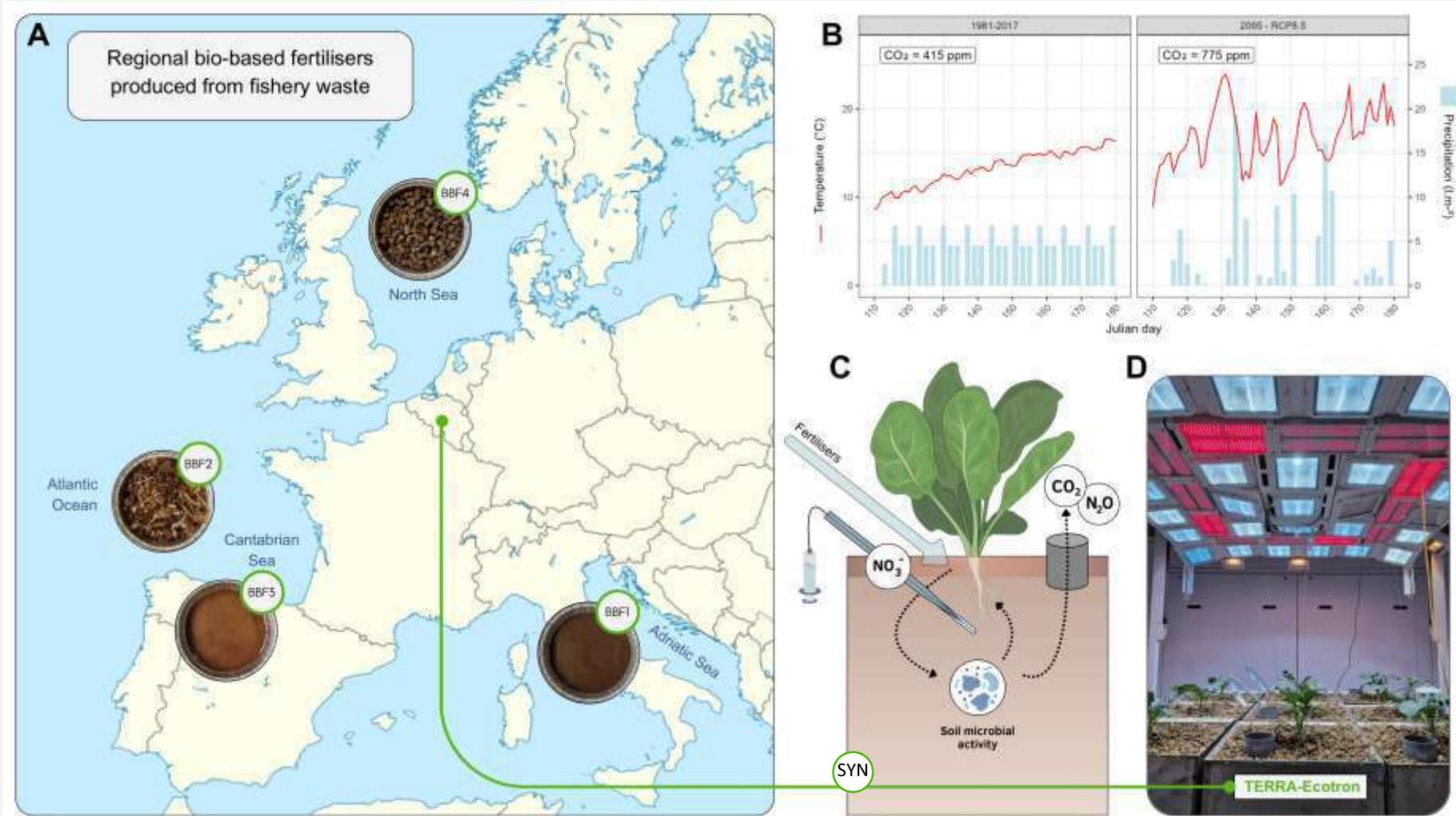
- Sampling consistency and filed data retrieval.
- Soil hydraulic parameters not measured.
- Soil moisture not continuously monitored.
- Only top-soil can be parametrised.
- DNDC v 9.5 omits several input prompts.
- Calibration of soil microbial activity.
- Calibration of crop parameters.
- Parametrisation of BBFs.



## Task 5.4 Ecotron trials. Lead: Uliège

**Objective:** To assess the **robustness of the prediction model** (task 5.3) in the highly controlled conditions of the ULIEGE Ecotron facilities which can reproduce any climates (actual or future) while growing crop(s).

- ✓ Test selected fertilisers under different climates representative of European regions
- ✓ Assess behavior and performance of selected fertilisers under present and future climatic scenario



J. Michel

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## Results summary

SYN mostly outperformed BBFs in the reference climate, in the future climate plants receiving BBFs had higher plant biomass and improved yield parameters compared to plants with SYN.

Cropping systems with **BBFs benefited from enhanced microbial activity and plants had higher nitrogen use efficiency than with SYN.**

**Still, further research is needed to limit the yield penalties observed under the future meteorological condition**



- The tested BBFs gave similar or higher yield than the commercial organic fertilisers on the market.
- Pot exp - P availability, high in FMP and CAT1.
- Pot exp - K, moderate availability, highest in FMP, high organic matter content (71%). FMP could substitute mineral K fertilizers.
- The DNDC model needs updating to include data from use of organic fertilizers. Modelling on yield in a changing climate showed lower yield possible depended on water availability.
- Ecotron experiment predicted plants receiving BBFs had higher plant biomass and improved yield parameters compared to plants with SYN in a changing climate.



# SEALAND

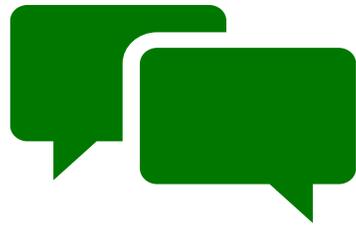


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**11:30-13:00 | BREAK-OUT SESSION**  
**Silver Room – Sea2land**



**Q&A**



## SEA2LAND: Production technologies for circular fertilisers

**Bruno Iñarra (AZTI)**

**Nagore Guerra (UVIC-NEIKER)**

**Sea2Land & NOVAFERT final conference, Brussels 5<sup>th</sup> June**



**01** Fisheries and aquaculture by-products: volumes generated and opportunities

**02** Baltic Sea Case Study

**03** Cantabrian Sea Case Study

**04** Adriatic Sea Case Study

**05** North Sea Case Study

**06** Atlantic Sea Case Study

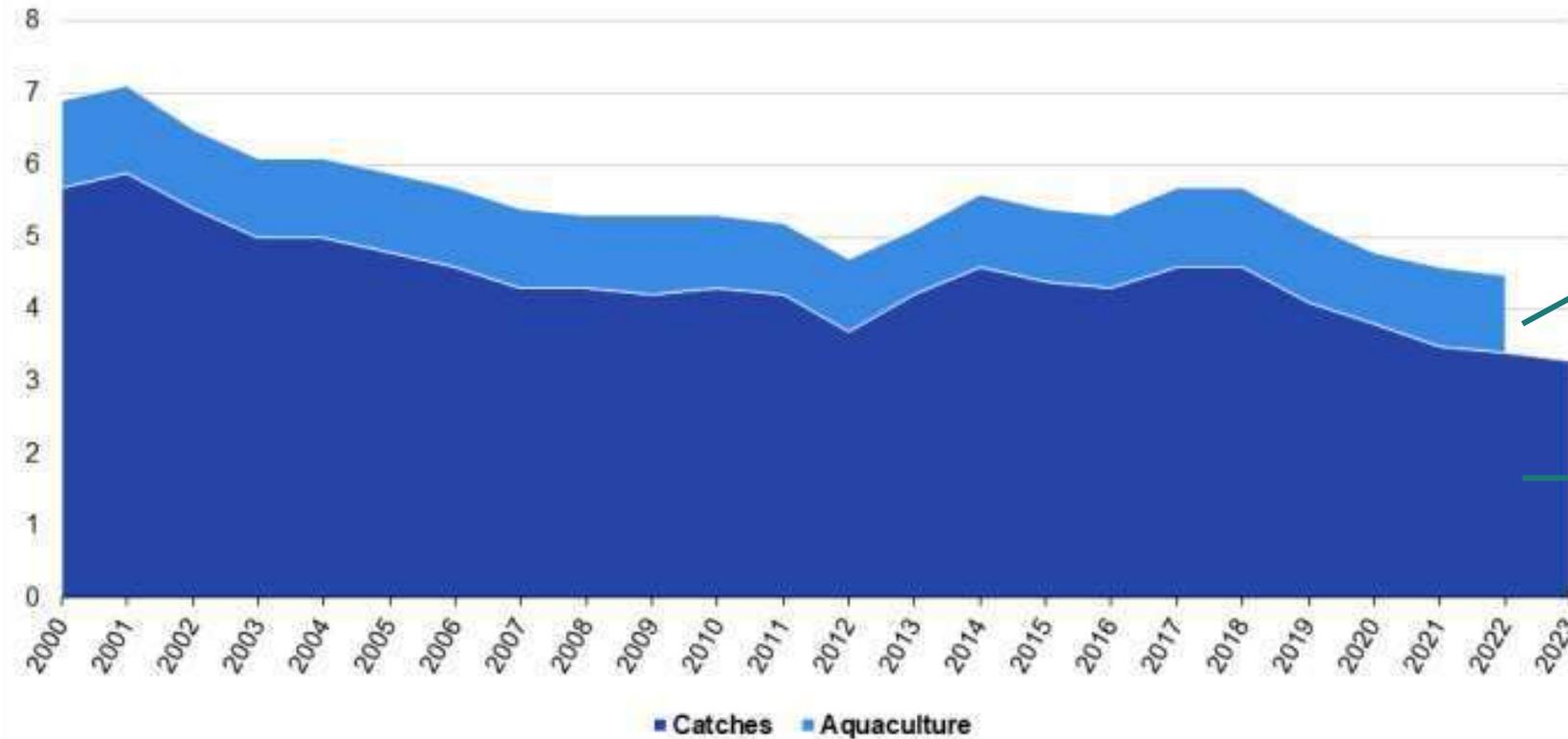
**07** Mediterranean Sea and Freshwater Aquaculture Case Studies

**08** Sea2Land fertilising products

**SEA2LAND**

**FISHERIES AND AQUACULTURE BY-PRODUCTS: VOLUMES GENERATED AND OPPORTUNITIES**

**Total production of fishery products**  
(million tonnes of live weight, EU, 2000-2023)



almost 1.1 million tonnes of aquatic organisms in 2023



3.3 million tonnes live weight in catches in 2023

Note: Substitute years have been used where there are a limited number of confidential data for catches and aquaculture.

Source: Eurostat (online data code: fish\_ca\_main, fish\_aq\_q and fish\_aq2a)



>70 % of total **fish caught** subjected to further processing (gutting, scaling, filleting...)

**20-80 % of fish waste** depending on processing and species: muscle-trimmings (15–20 %),

- skin and fins (1–3 %),
- bones (9–15 %),
- heads (9–12 %),
- viscera (12–18 %),
- scales (5 %)

In **mussels**:

- Shell 30-60 % of total mass
- Byssus 1-3 % of total mass



- Fish waste from processing equivalent to catches
- Fish feed: approximately **10 % of the feed** is not consumed, and 13 % becomes faeces.
- **Wastewater** that generates a **solid waste** composed by feed, faeces, detached biofilm, sediments and substrates. Sludge production depends on the species



Sources: Iñarra et al., 2018; Coppola et al., 2021



**Fish waste in average** contains 49.22–57.92 % of protein, 21.79–30.16 % of ash, and 7.16–19.10 % of fat (in dry basis)

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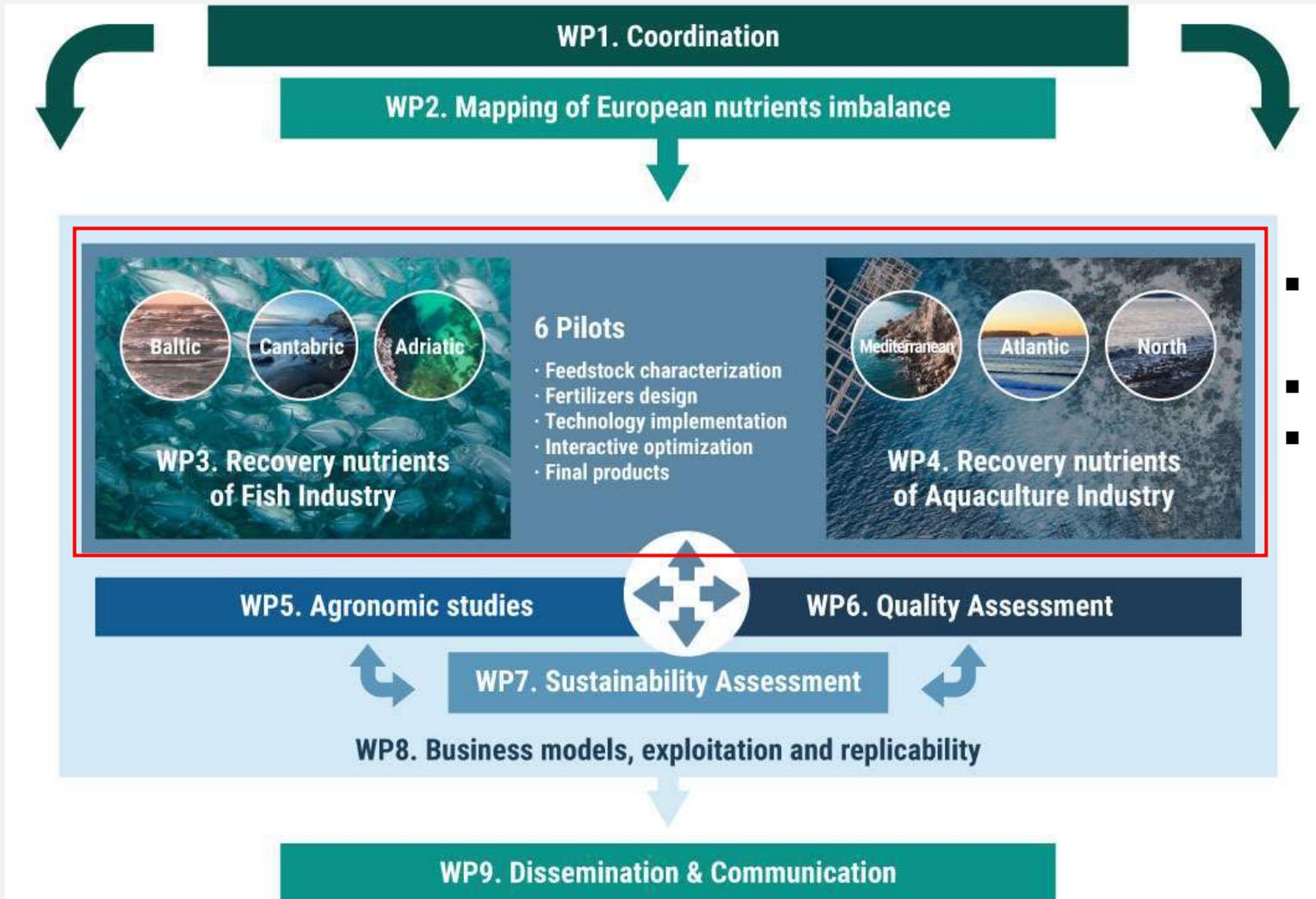


**Sludge** retains 10-30 % of total nitrogen and 30-80 % of total phosphorus contained in the wastewater

### Industrial application of by products

- **Animal feed:** fishmeal, fish oil
- **Human health:** pharmaceutical, nutraceutical
- **Cosmetics:** skincare
- **Agriculture:** soil improvers, fertilizers and protein hydrolysates

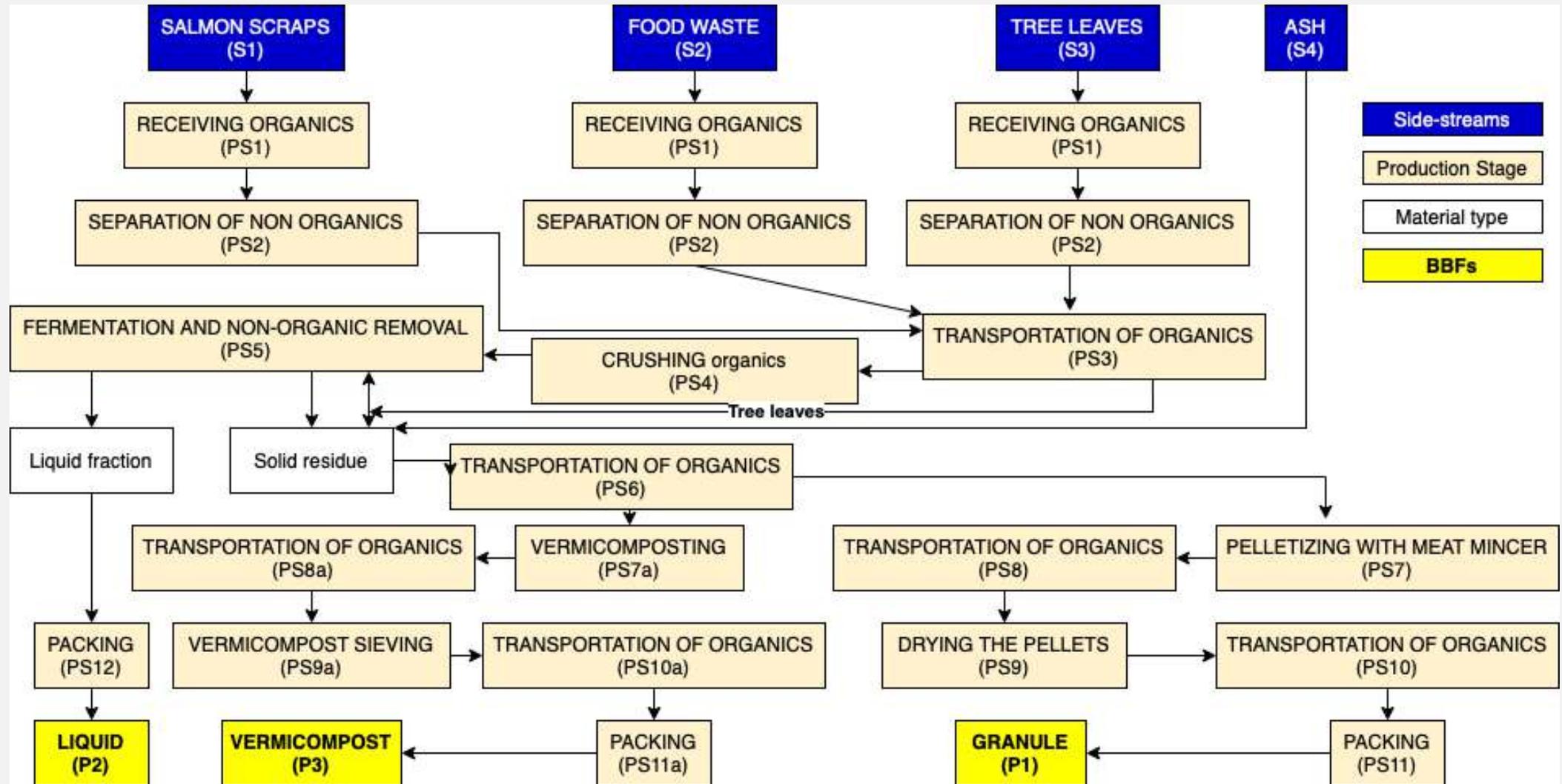




- 6 different **technological approaches** in 7 case studies
- **Various feedstocks**
- Wide **portfolio of fertilising products** after technology optimisation

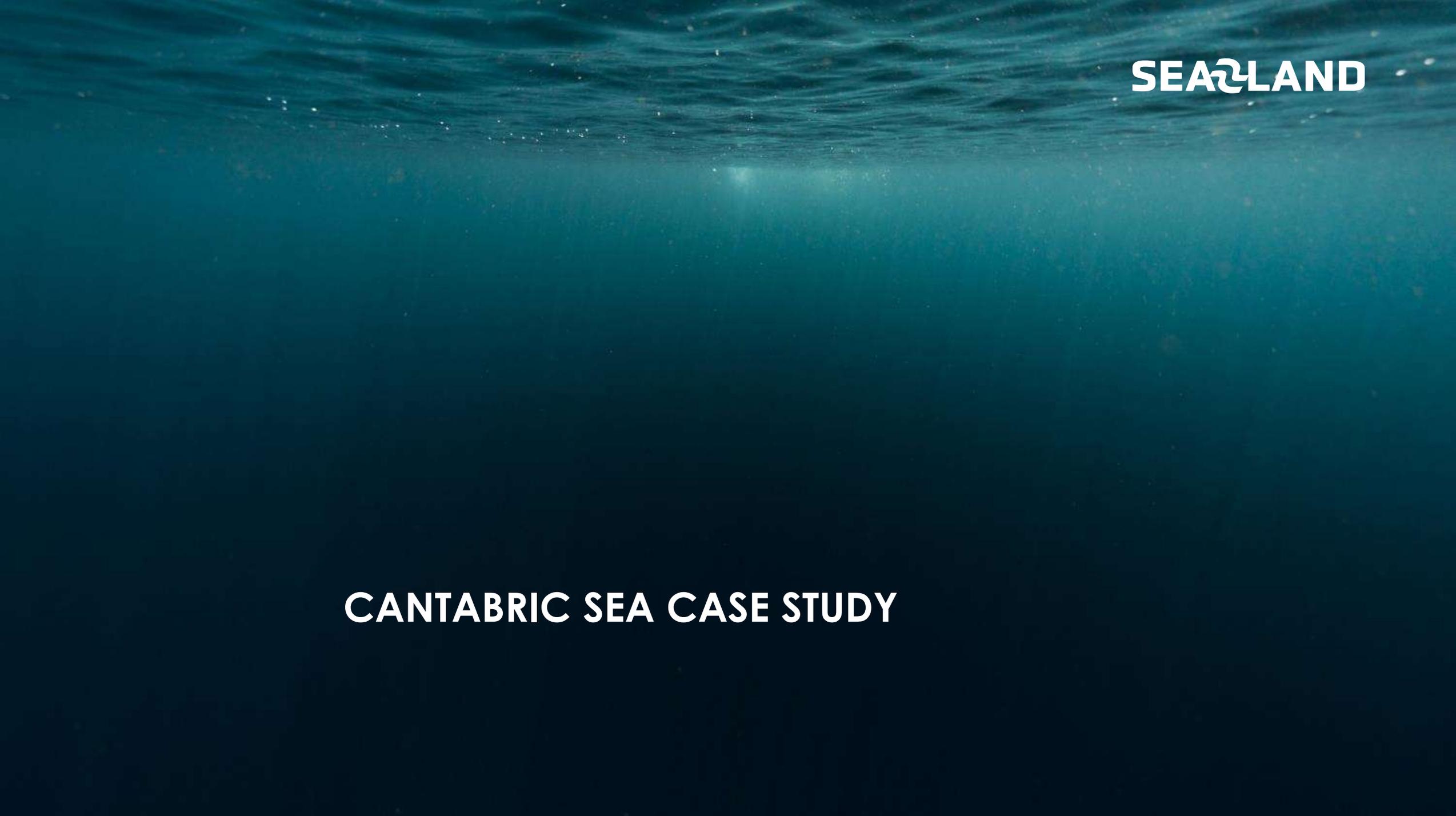
**SEA2LAND**

# **BALTIC SEA CASE STUDY**



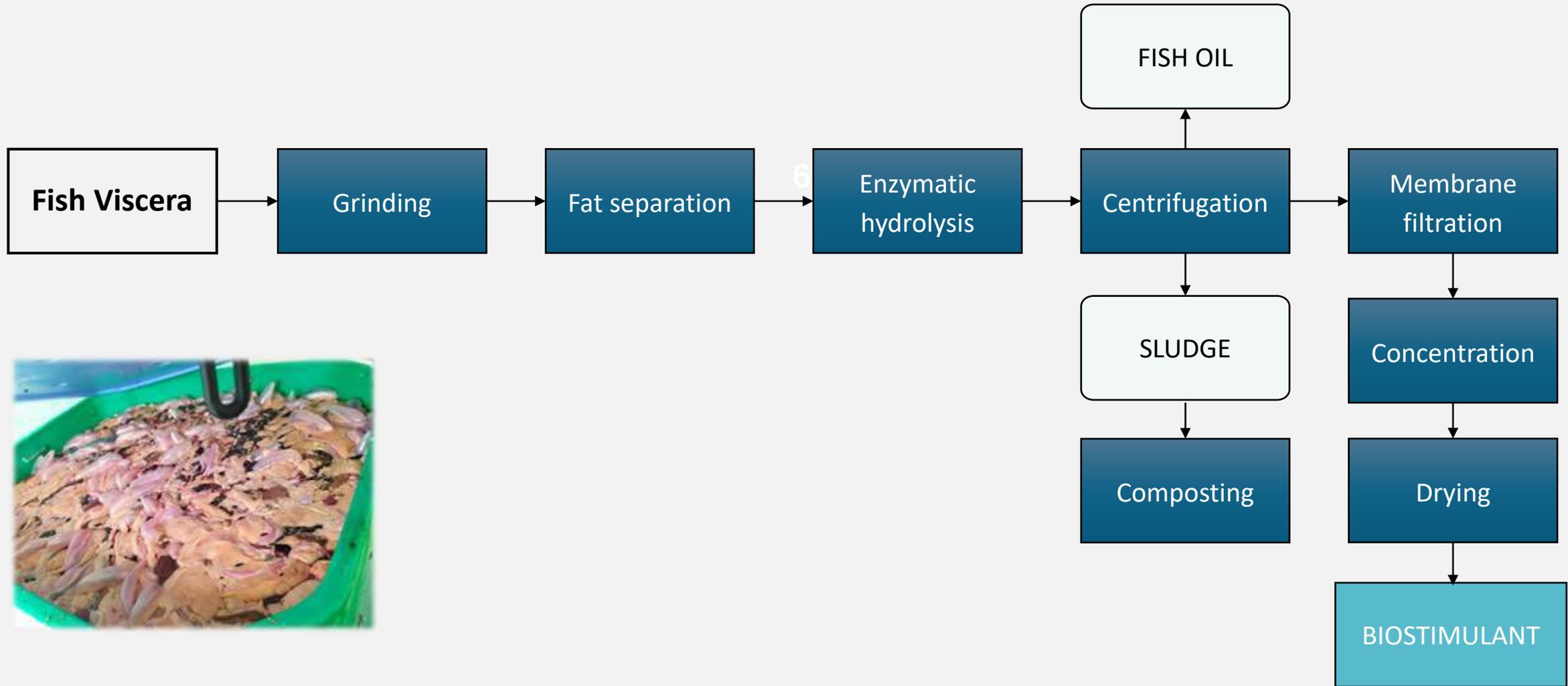
### Key findings:

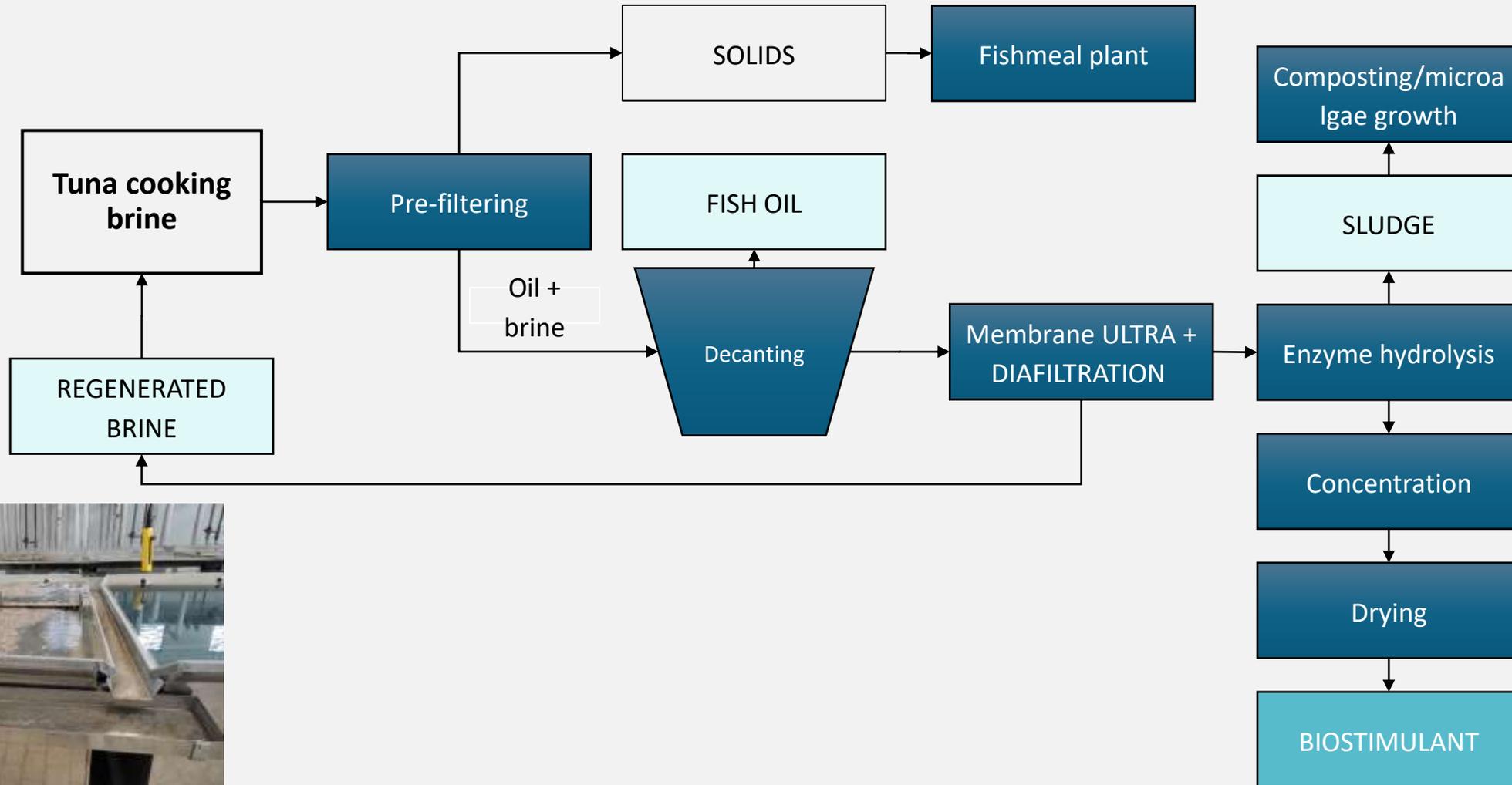
- **Fish waste** combined with other biowastes can be used as key ingredient to produce **biofertilisers**, alone or in formulation with other ingredients in a commercial scale solution
- **Bokashi fermentation, combined with granulation or vermicomposting** can be used as valorisation strategy for fish waste
- **Microbiological spoilage** can be a **critical bottleneck** affecting
  - **Bokashi fermentation:** rooting and other unsuitable process must be prevented.
  - Raw material should be frozen or stabilised (bran or ash addition)

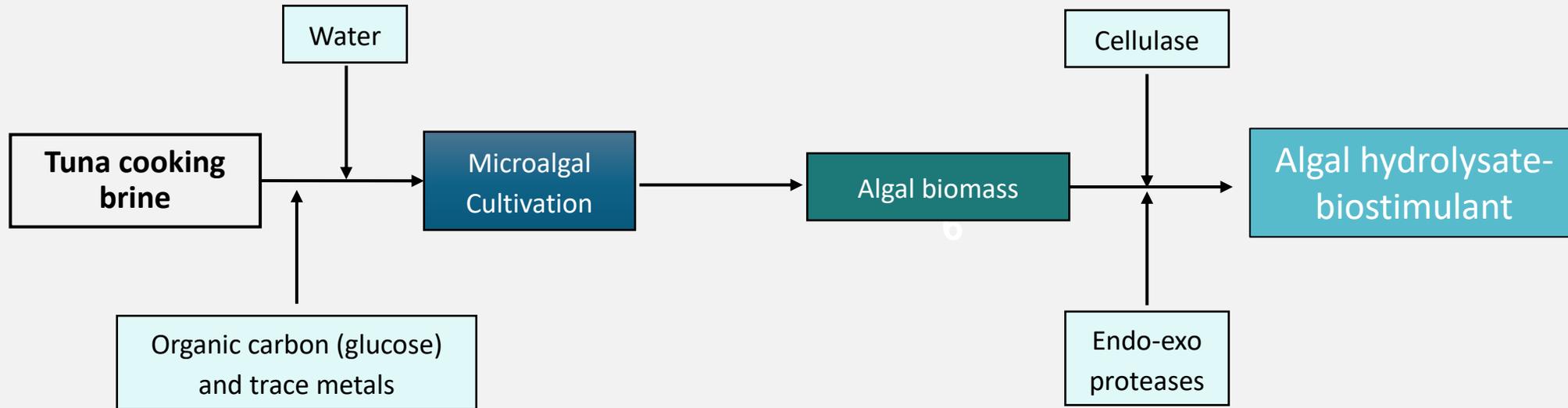


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# **CANTABRIC SEA CASE STUDY**





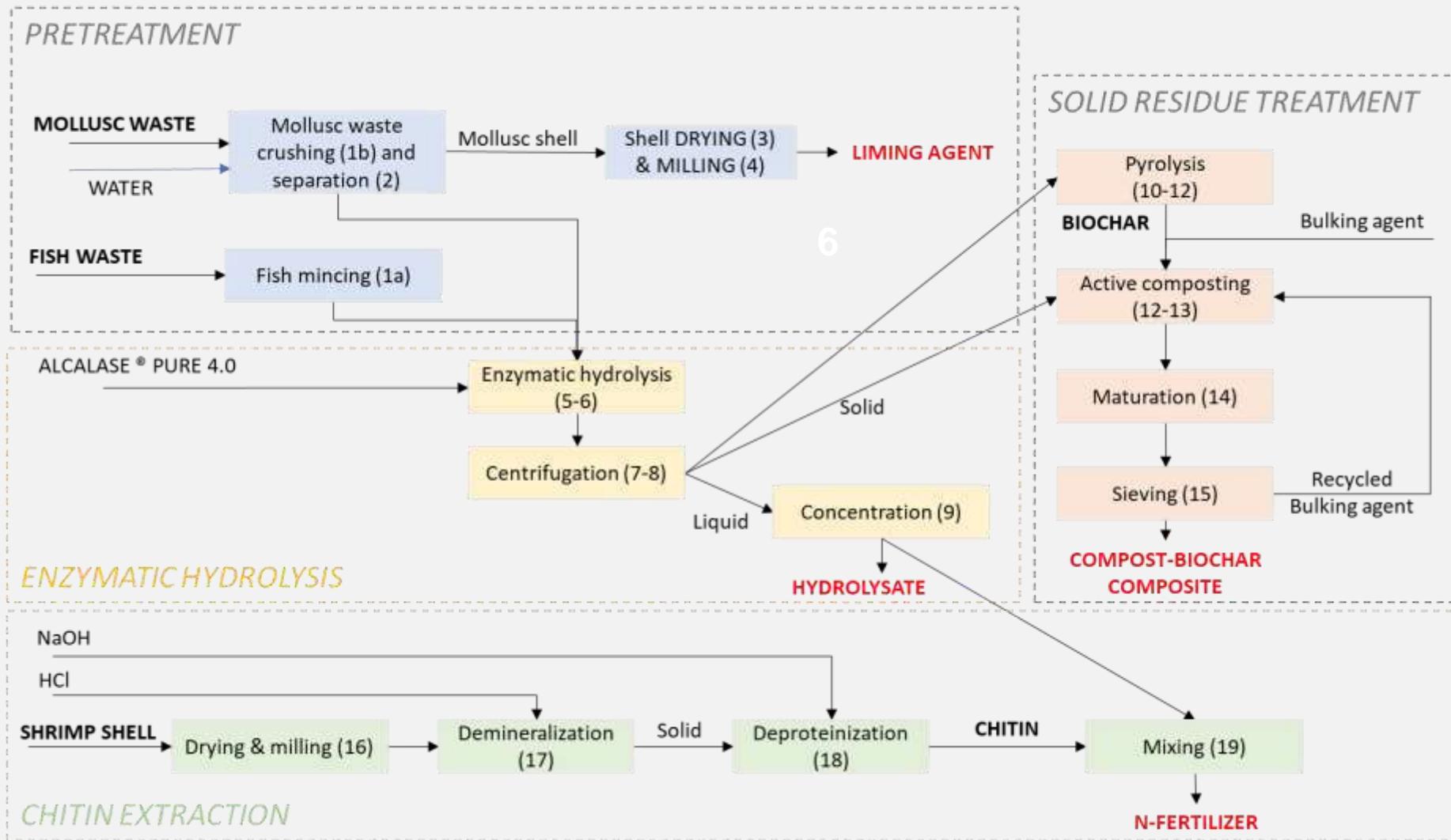


### Key findings:

- **Fish viscera** is a very good source of amino acids for the production of **biostimulants**
  - **Silage** is the most promising technology for the production of free aminoacids
  - High **fat** content in viscera is a **profitable co-product** but difficult to handle
  - Reduction of water use is a key factor to improve economic and environmental results
- **Tuna cooking waters** contain interesting amount of protein
  - High salt content might limit its use
  - Difficult to transform into free a.a.
  - Proper management of raw material is necessary to avoid spoilage and biogenic amines
- Feasibility of using a **marine microalgae** to revalorize tuna cooking waters into a valuable biomass that can be turned into a plant **biostimulant** was demonstrated
  - The use of tuna cooking water reduced the cost of the culture medium by 90 %

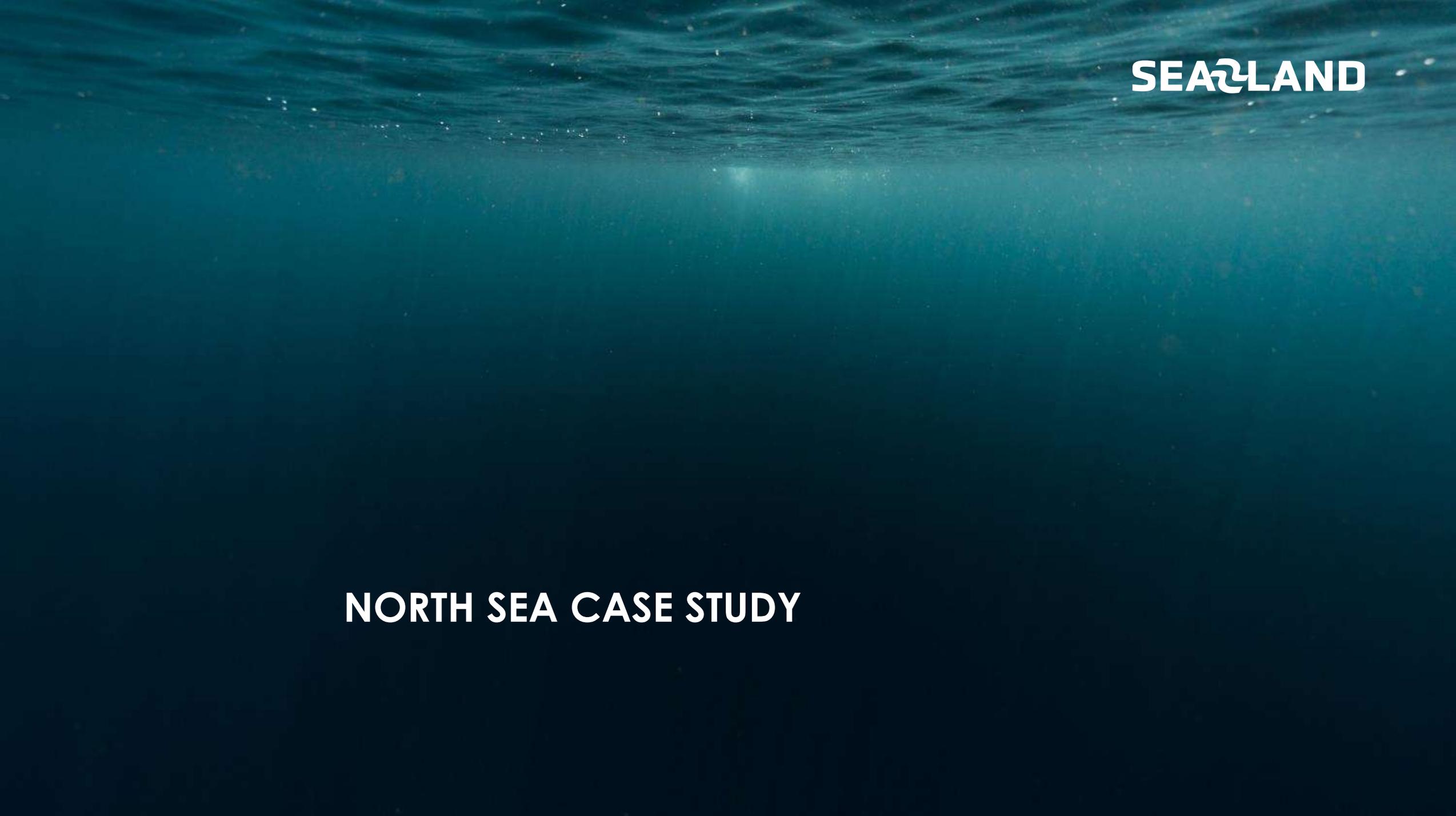
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# **ADRIATIC SEA CASE STUDY**



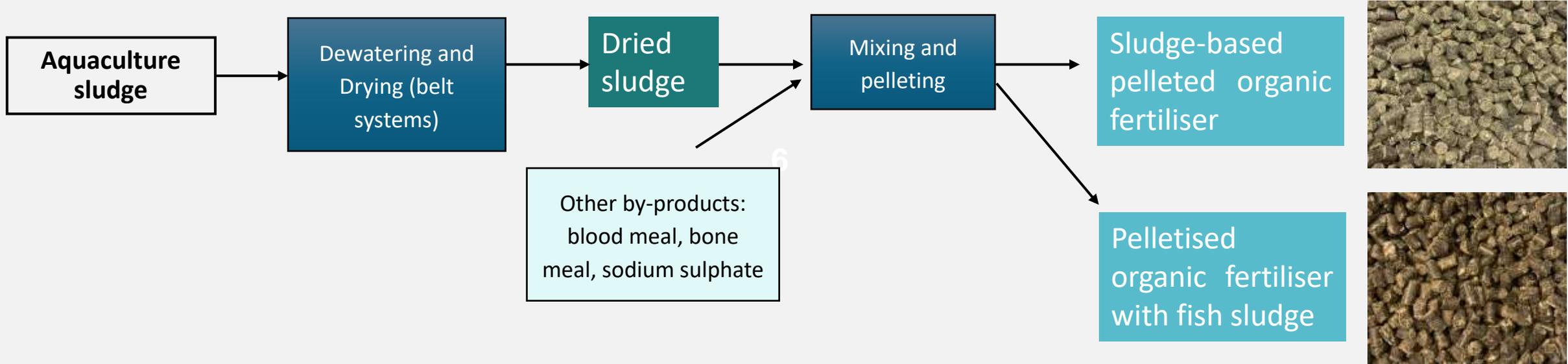
### Key findings:

- **Mussel shells** can be used to produce a **liming agent**
- **Mussel can be combined fish waste** to produce **bioestimulants** and **compost biochar composite**
- **Shrimp shell** can be used to produce **N-fertilisers**
- Avoiding raw material spoilage is crucial



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**NORTH SEA CASE STUDY**



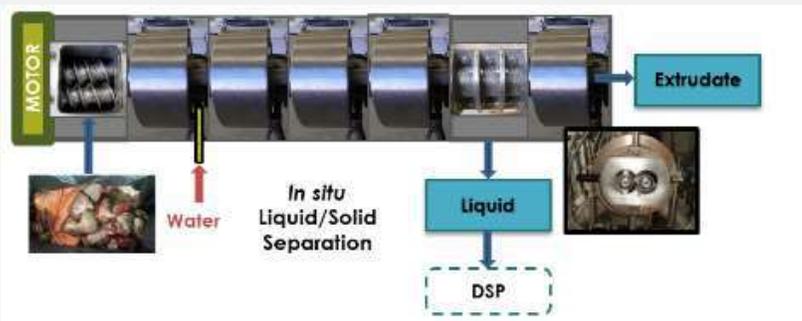
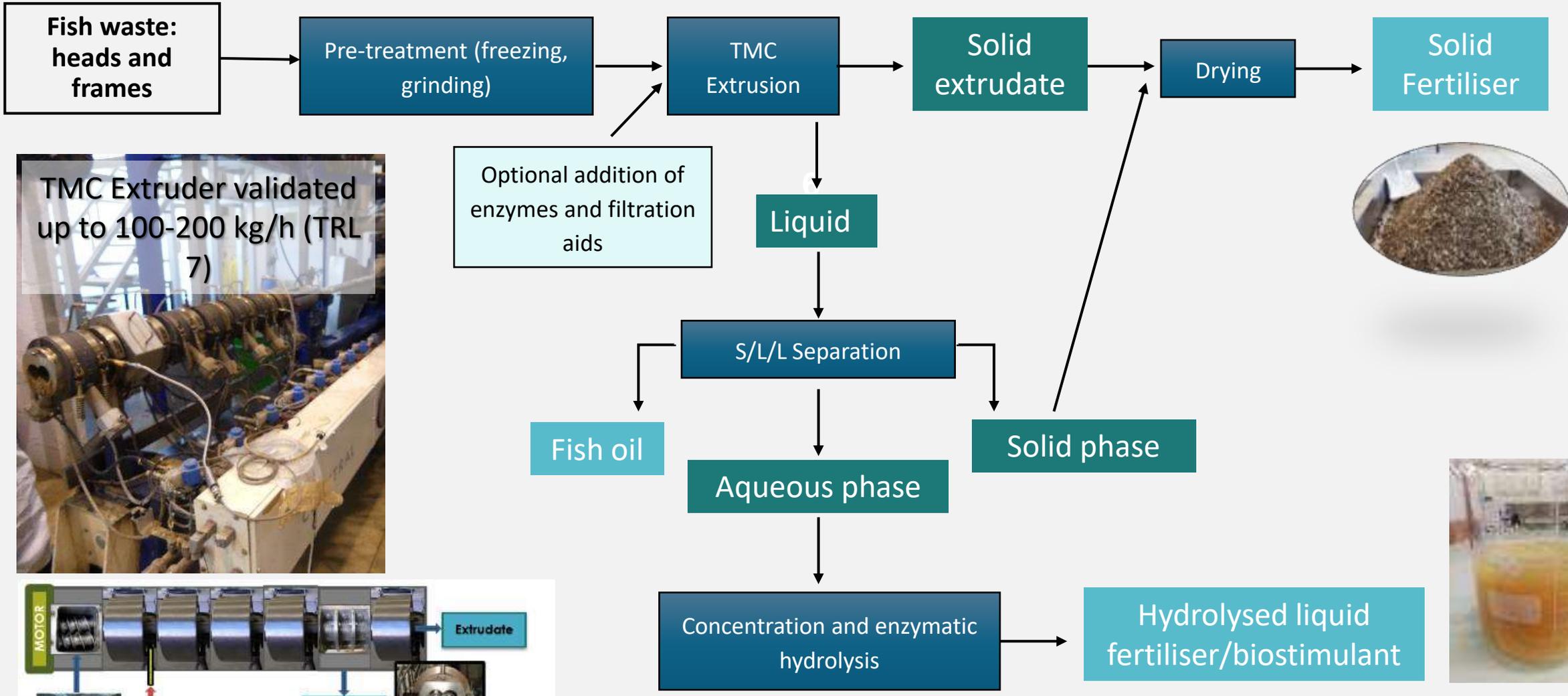
### Key findings:

- **Fish sludge** as key ingredient for **pelletised organic fertilisers**, alone or in formulation with other ingredients in a commercial scale solution
- **Mature market** for organic fertilising products from fish sludge in Norway, authorised for organic farming
- **Drying** of fish sludge as the **critical bottleneck** affecting
  - **Energy efficiency.** New and more efficient higher-temperature steam-driven drying. Incorporates sanitisation.
  - Temperature-time co-factors affecting **nitrogen losses by ammonia volatilisation.** No clear trends



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**ATLANTIC SEA CASE STUDY**

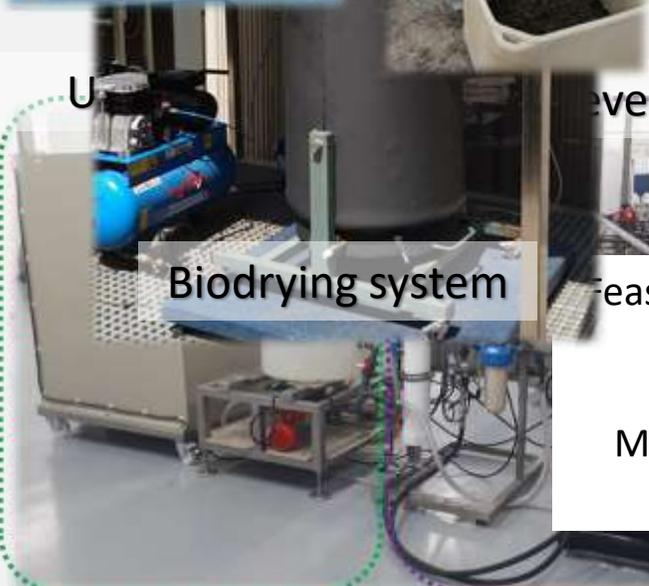
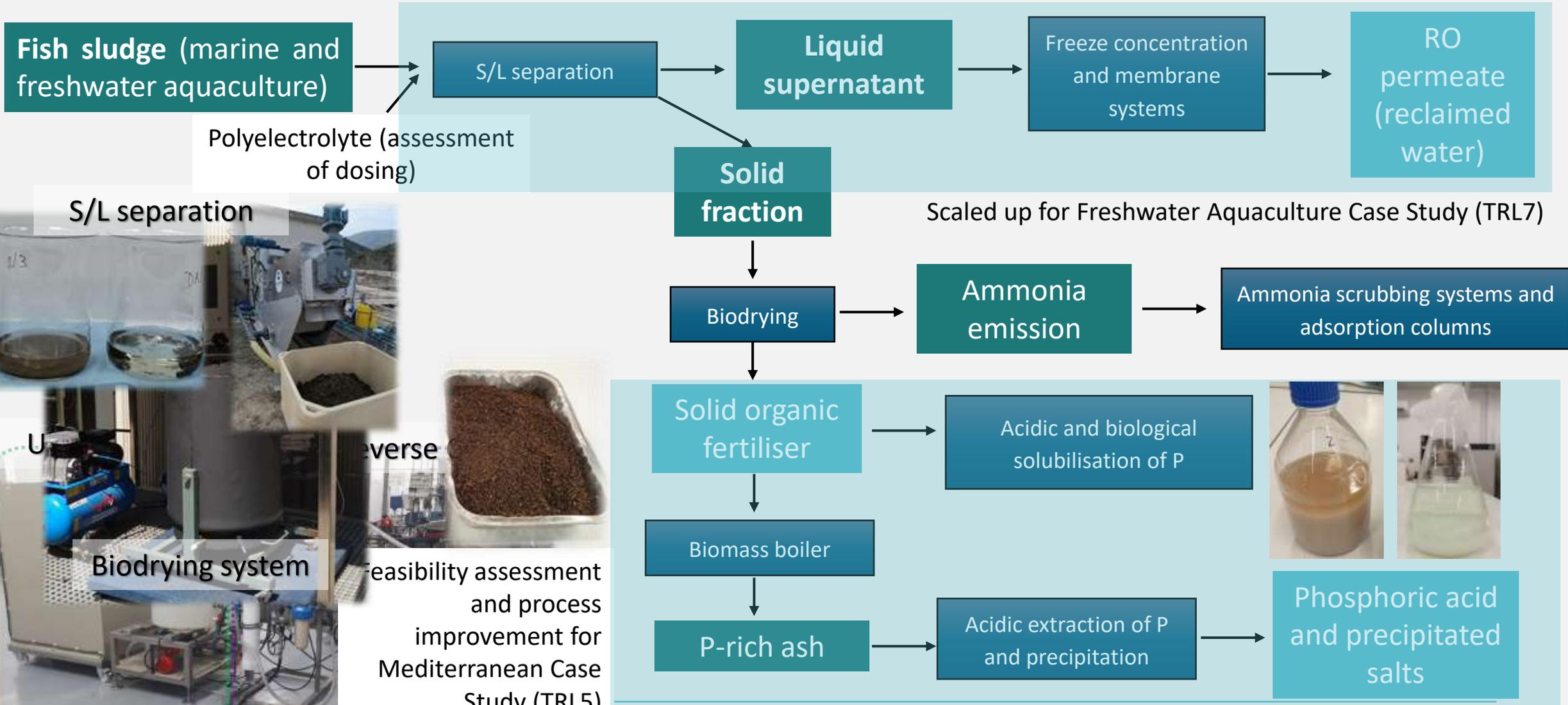


### Key findings:

- **Fish waste fractionation by twin-screw extrusion** (TMC process) **validated** and **scaled up** (up to TRL7).
  - Continuous fractionation technology
  - Free enzymes process
  - Mechanical effect is the main affecting factor: use of filtration aids, avoiding excessive grinding.
  - Use of filtration aids improves process robustness and protein and lipid recovery efficiencies (> 70 %)
  
- **Main product** = Solid extrudate as **organic fertiliser**
- **Additional valuable co-products**
  - **Concentrated liquid** product as **liquid fertiliser** and as **biostimulant** after **enzymatic hydrolysis** (optimal duration and concentrated liquid/enzyme ratio 2-3 % dose)
  - **Fish oil**
  
- The efficiency of the solid extrudate's **drying** may be improved by industrial processes able to reuse lost energy in circular bioeconomy concept.

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**MEDITERRANEAN SEA AND FRESHWATER CASE STUDIES**



Polyelectrolyte (assessment of dosing)

S/L separation

Biodrying system

Feasibility assessment and process improvement for Mediterranean Case Study (TRL5)

Scaled up for Freshwater Aquaculture Case Study (TRL7)

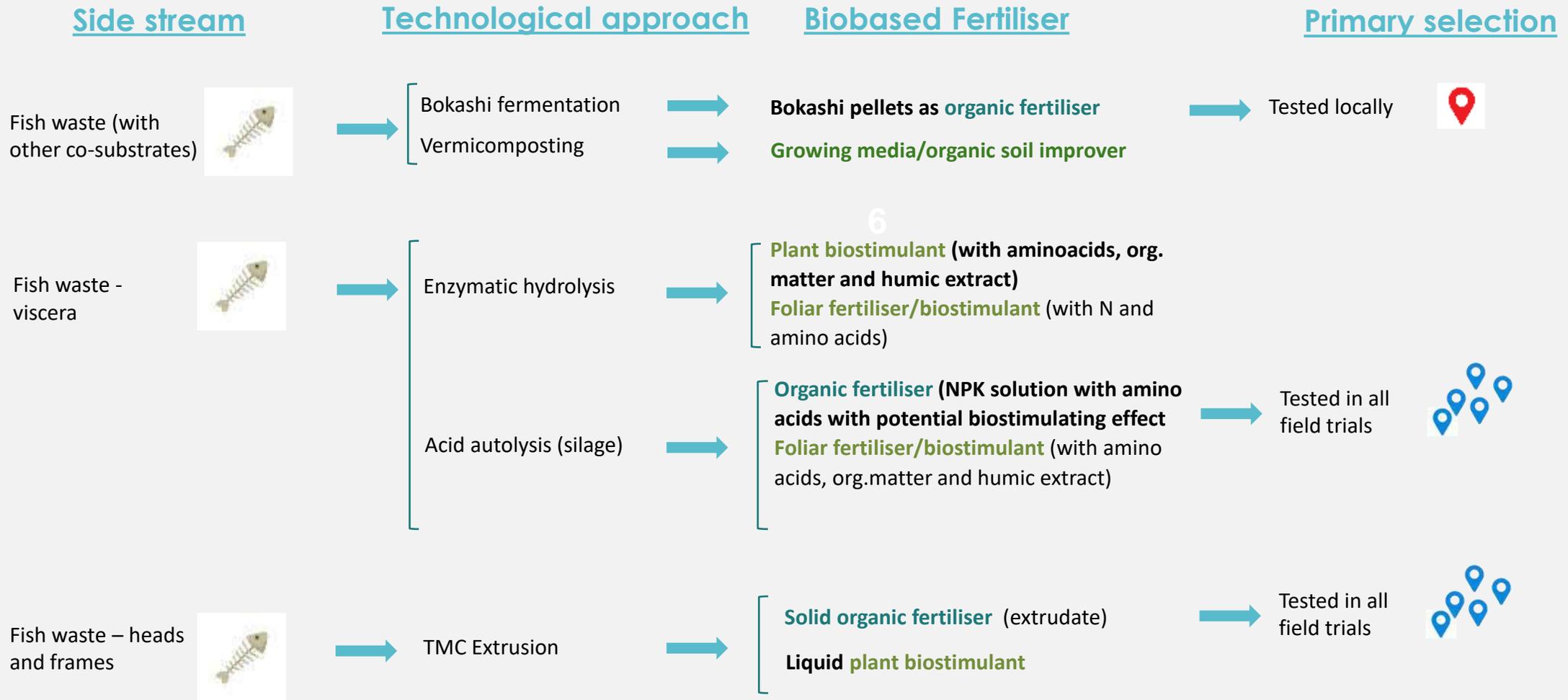


### Key findings:

- Fish sludge **dewatering** with addition of polyelectrolytes required, adjustment to fish sludge source and separation unit
- **Treatment of liquid fraction** re-designed towards recovery of **reclaimed water** instead of liquid fertilisers due to too diluted nutrients. Direct use of Reverse Osmosis is feasible if efficient solid/liquid separation is achieved. **Improved energy efficiency** in **upscaled** systems
  - Reclaimed water gathers the **appropriate characteristics** for certain authorised uses
- **Biodrying** process is satisfactory to obtain **solid organic or organo-mineral fertilisers**
  - **Ammonia gaseous emissions** are a major bottleneck and feasibility of **adsorption systems** have been validated with zeolites
- **Low phosphorus availability** in solid organic fertiliser was addressed in two ways: 1) solubilization (acidic and biological) trials; 2) combustion and acidic extraction of P from ash.
  - **Biological solubilisation** was not satisfactory and there is room of improvement in that line
  - **Combustion** with complementary material needed
  - **Acidic extraction** was assessed with different acids, mixing ratios and in cumulative extraction trials. **Cumulative extraction** allows reaching an interesting product (**phosphoric acid**)
  - **P precipitation** is feasible but not efficient from mass efficiency point of view. Low recovery yield in salt.

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**SEA2LAND FERTILISING PRODUCTS**



## Side stream

## Technological approach

## Biobased Fertiliser

## Primary selection

Mollusc waste (and fish waste)



- Enzymatic hydrolysis (organic fraction)
- Composting
- Pyrolysis (shell)
- Crushing and grinding (shell)



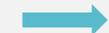
**Organic fertiliser (with potential biostimulating effect)**

**Growing media/organic soil improver**

**CaCO<sub>3</sub>\*/ Liming agent**



Tested locally



Tested locally



Tuna cooking brine



- Enzymatic hydrolysis
- Microalgae cultivation



**Liquid plant biostimulant**



**Microalgae-based plant biostimulant**



Tested locally



Aquaculture sludge



- Formulation and pelleting
- Biodrying and potential thermal treatment + acidic extraction



**Fish-sludge based pelletised organic fertiliser**  
**Fish mix pelletised organic fertiliser**



**Organic or organo-mineral fertiliser**  
**Inorganic fertiliser (ash/phosphoric acid)**



Tested in all field trials



Tested locally



Tested locally



# SEALAND

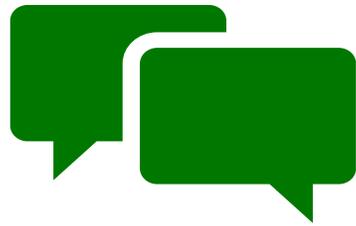


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## PARTNERS



**11:30-13:00 | BREAK-OUT SESSION**  
**Silver Room – Sea2land**



**Q&A**



## Quality and Safety Assessment of Circular Fertilizers

Çağrı Akyol  
Ghent University



Waste Management 113 (2019) 45–112

Contents lists available at ScienceDirect



**Waste Management**

journal homepage: [www.elsevier.com/locate/wasman](http://www.elsevier.com/locate/wasman)

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**Fish and fish waste-based fertilizers in organic farming – With status in Norway: A review**

Ishita Ahuja <sup>a,\*</sup>, Egidijus Dauksas <sup>b</sup>, Jannicke F. Remme <sup>c</sup>, Roger Richardsen <sup>d</sup>, Anne-Kristin Løes <sup>e</sup>



Aquaculture 500 (2019) 492–499

Contents lists available at ScienceDirect



**Aquaculture**

journal homepage: [www.elsevier.com/locate/aquaculture](http://www.elsevier.com/locate/aquaculture)



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**Aerobic bioconversion of aquaculture solid waste into liquid fertilizer: Effects of bioprocess parameters on kinetics of nitrogen mineralization**

Zied Khiari, Soba Kaluthota, Nick Savidov <sup>\*</sup>



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*Review*

**Fish Viscera Hydrolysates and Their Use as Biostimulants for Plants as an Approach towards a Circular Economy in Europe: A Review**

Haizea Dominguez <sup>1</sup>, Bruno Iñarra <sup>1,\*</sup>, Jalel Labidi <sup>2</sup> and Carlos Bald <sup>1</sup>



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*Article*

**Solar-Dried Biofertilizers from Marine Waste: Enhancing the Circular Economy**

Beatriz Castillo-Tellez <sup>1</sup>, Margarita Castillo Tellez <sup>2,\*</sup>, Martha Fabiola Martin del Campo <sup>3,\*</sup>, Edgar Oswaldo Zamora González <sup>3</sup>, Alfredo Dominguez Niño <sup>4</sup> and Gerardo Alberto Mejia-Pérez <sup>1</sup>

Journal of Environmental Management 348 (2023) 119266

Contents lists available at ScienceDirect



**Journal of Environmental Management**

journal homepage: [www.elsevier.com/locate/jenvman](http://www.elsevier.com/locate/jenvman)



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*Review*

**Nutrient recovery and recycling from fishery waste and by-products**

Jingsi Zhang, Çağrı Akyol <sup>\*</sup>, Erik Meers



Waste Management 166 (2023) 294–304

Contents lists available at ScienceDirect



**Waste Management**

journal homepage: [www.elsevier.com/locate/wasman](http://www.elsevier.com/locate/wasman)



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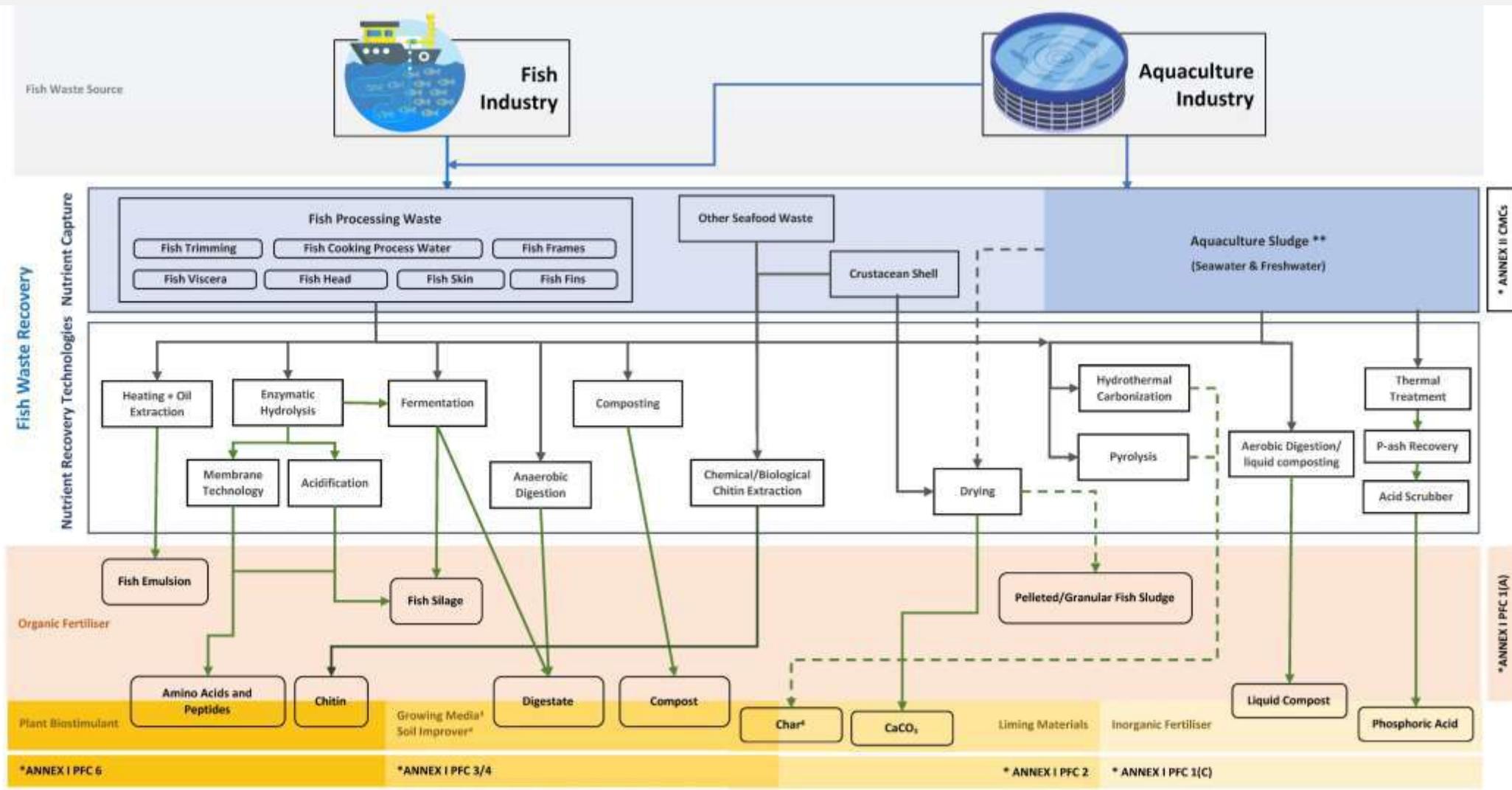
*Research Paper*

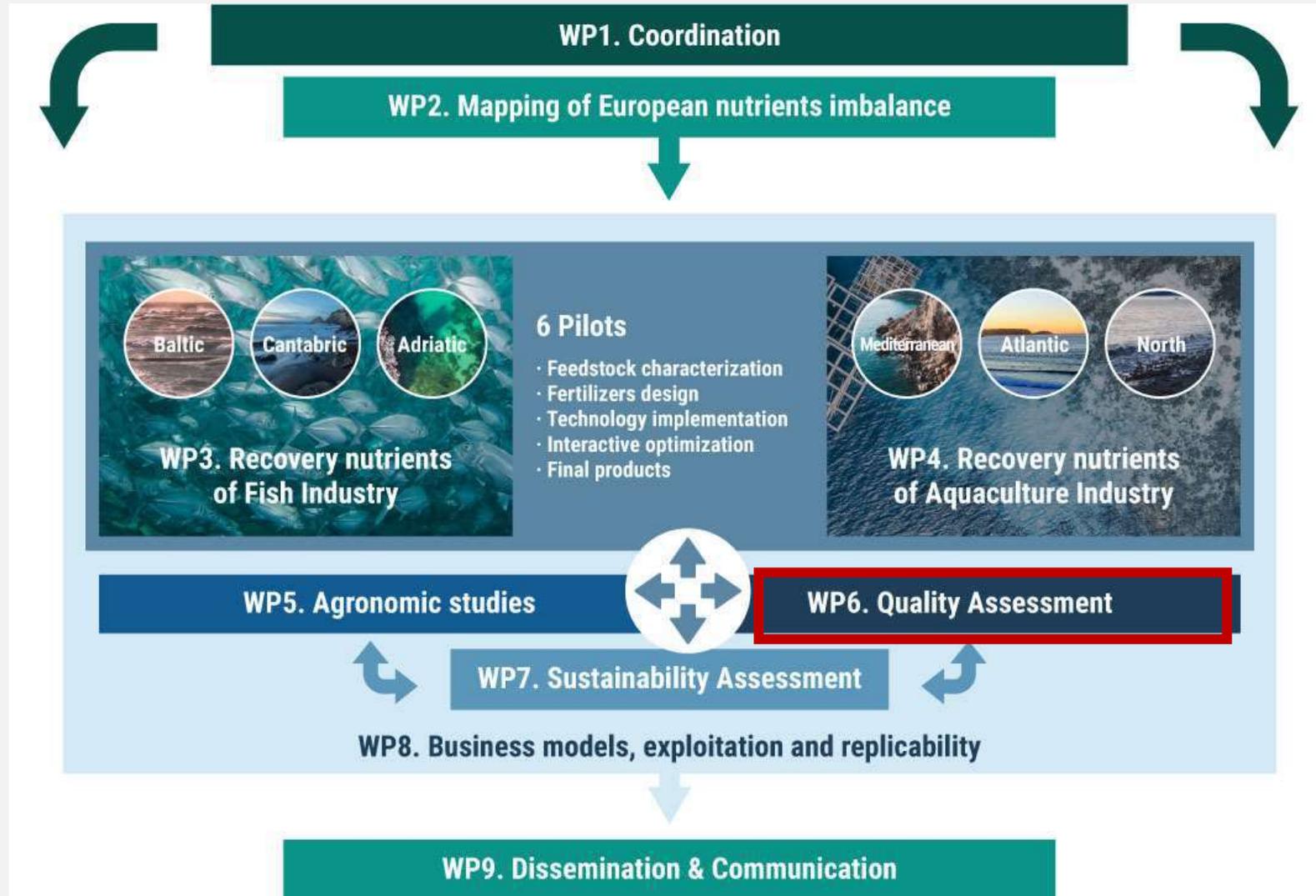
**Techno-economic assessment of biorefinery scenarios based on mollusc and fish residuals**

C. Andreola <sup>a</sup>, J. González-Camejo <sup>a,\*</sup>, F. Tambone <sup>b</sup>, A.L. Eusebi <sup>a</sup>, F. Adani <sup>b</sup>, F. Fatone <sup>a</sup>



# Circular fertilizers from fishery waste and by-products

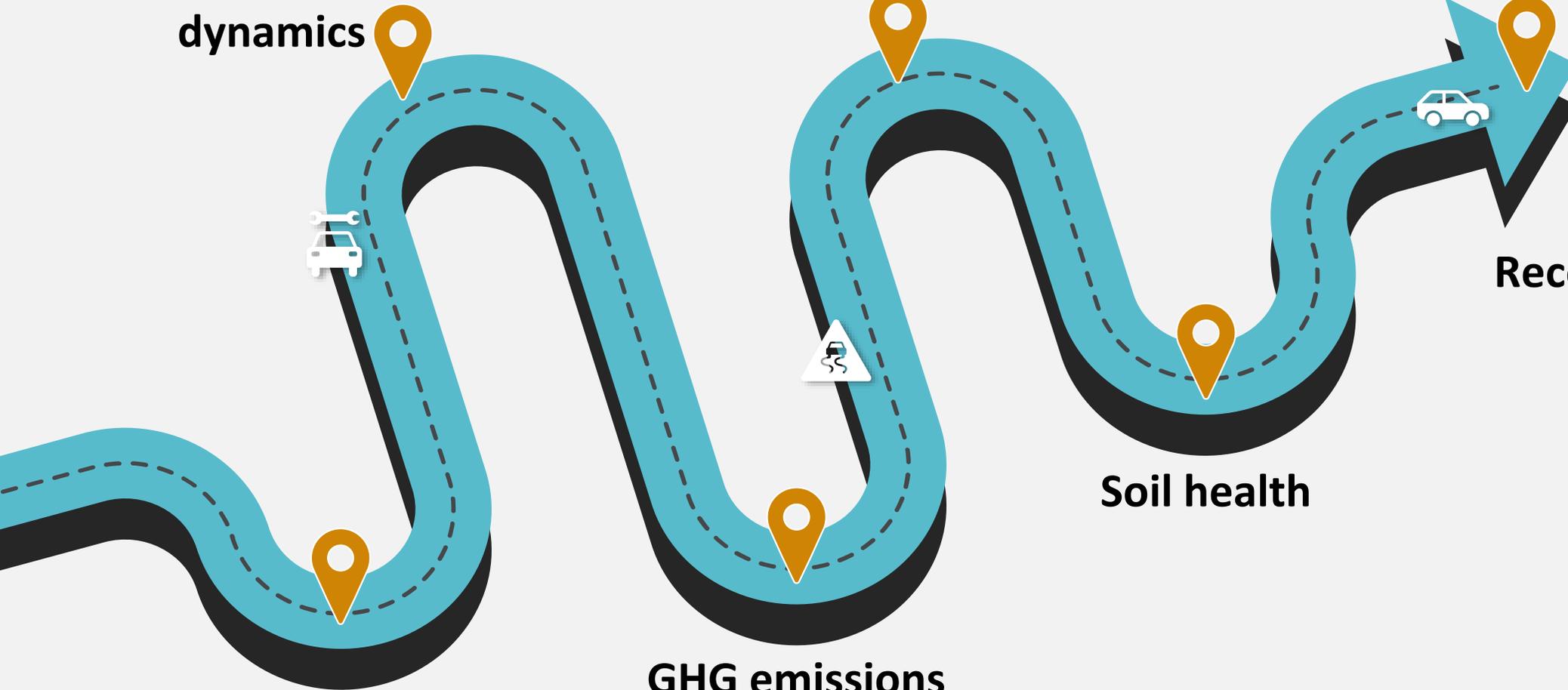




Nitrogen mineralization dynamics

Microplastics

Recommendations



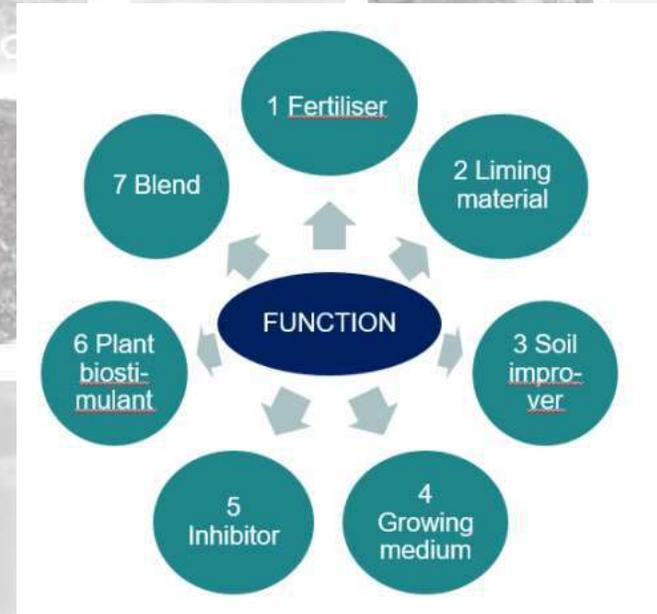
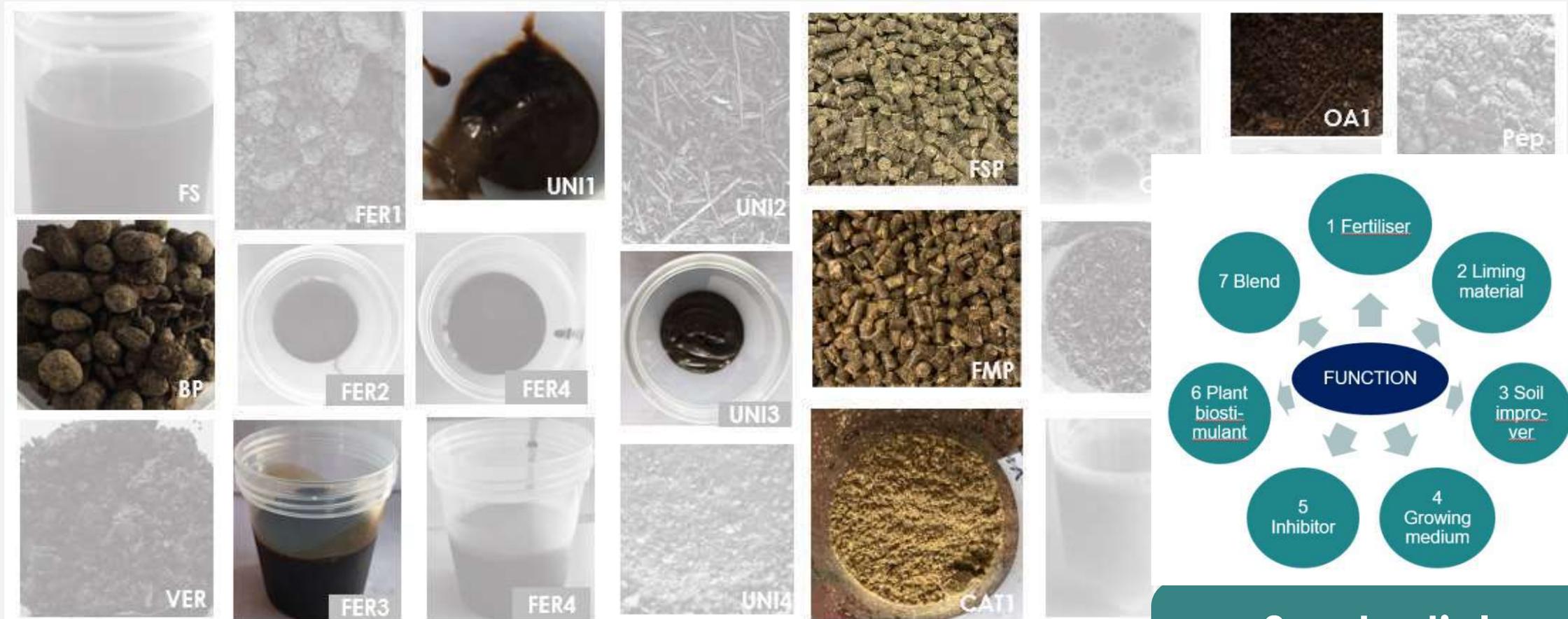
Characterization

GHG emissions

Soil health

# Fertilizing products





**8 potential (organic) fertilizers**



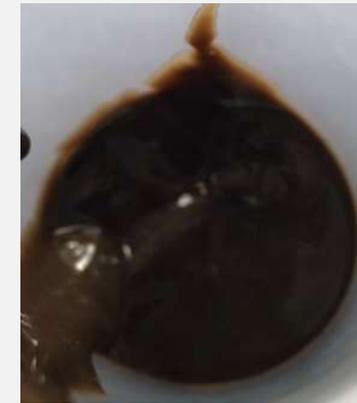
**Bokashi pellet  
(BP)**



**Organic amendment after  
filtration, flocculation,  
biodrying (OA1)**



**NPK solution with  
amino acids after  
autolysis (FER3)**



**Amino acids and  
peptides (UNI1)**



**N fertilizer with chitin  
(UNI3)**



**Protein fraction after  
TMC twin-screw  
extrusion (CAT1)**

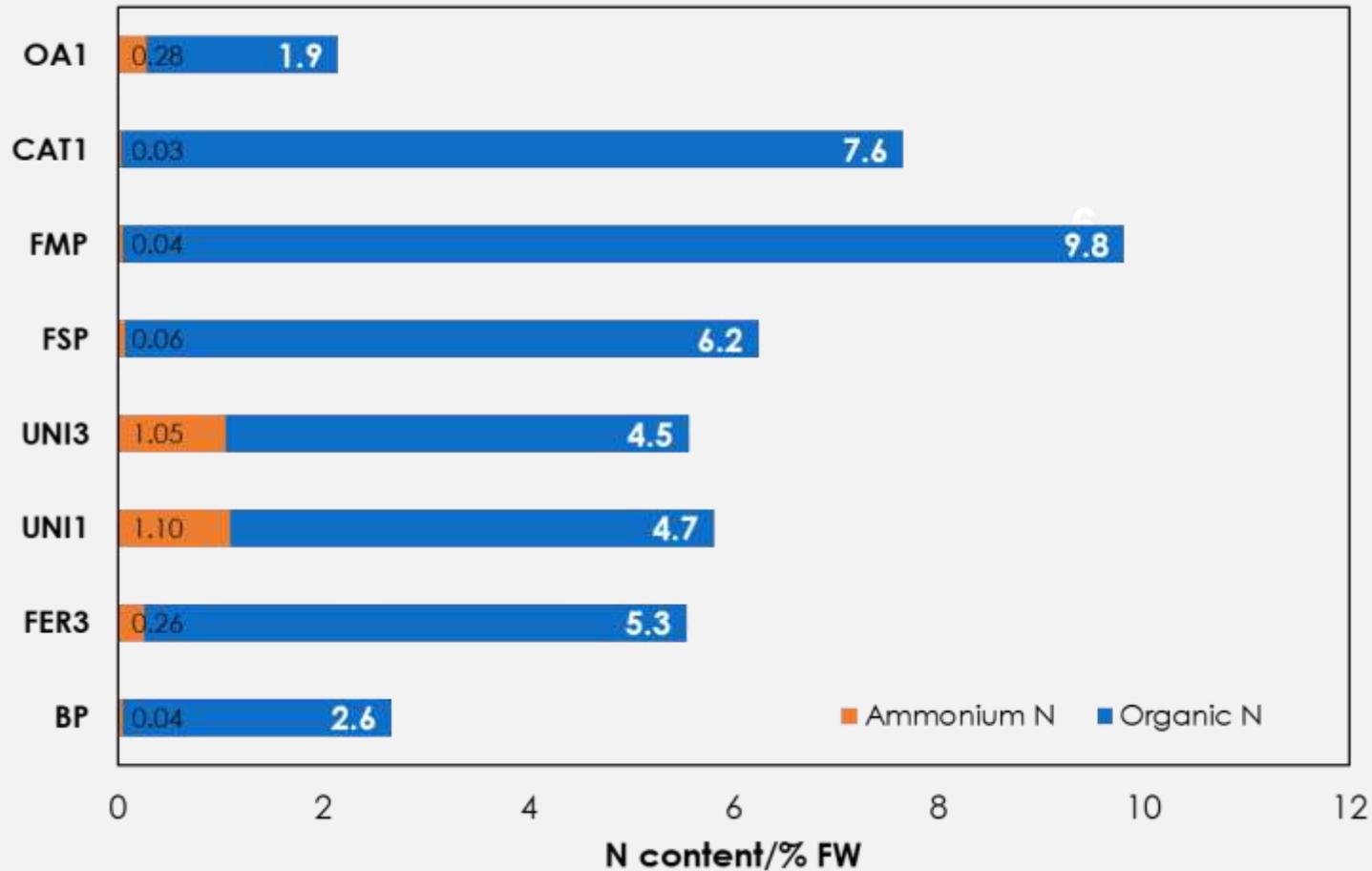


**Fish sludge pellet  
(FSP)**

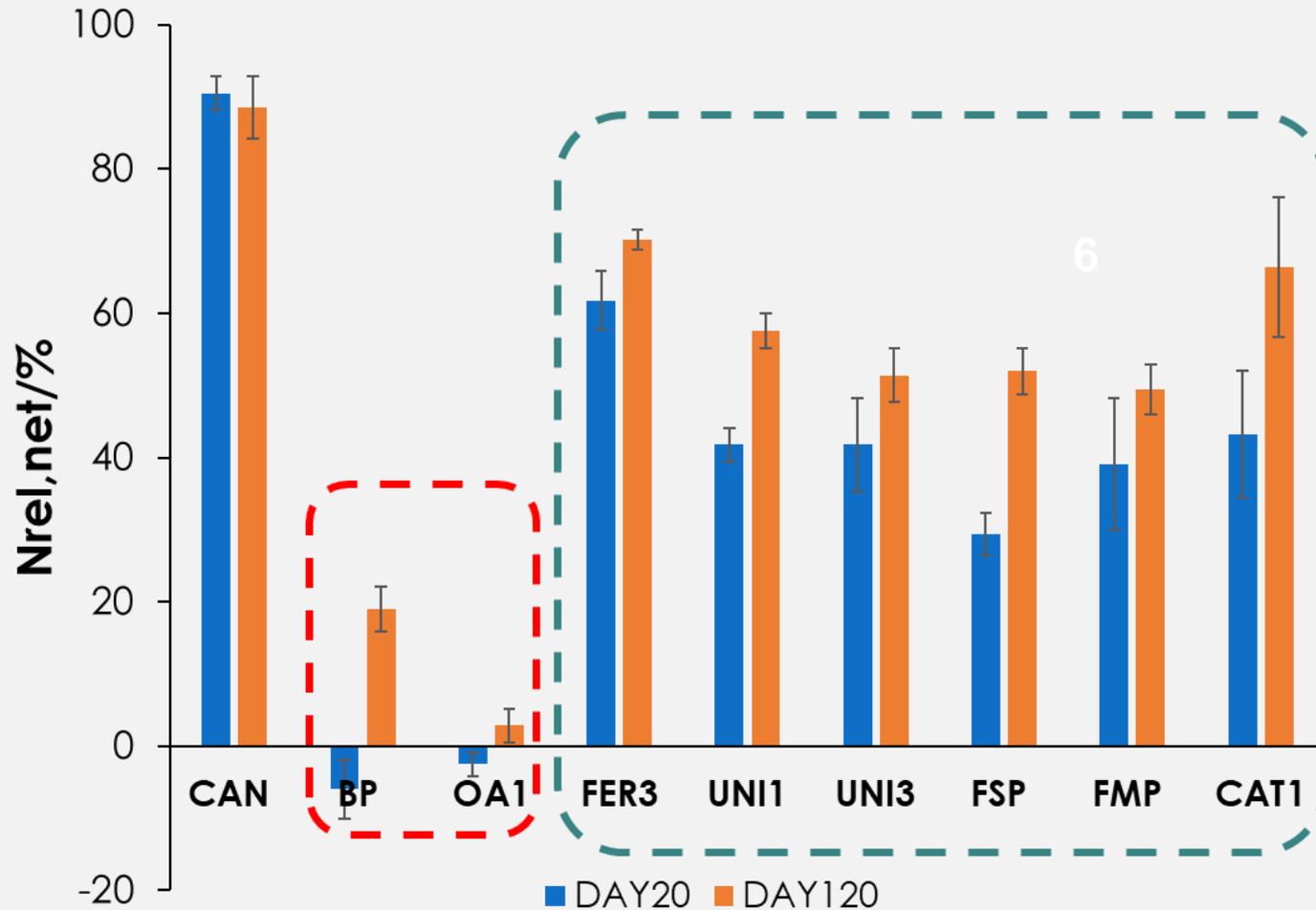


**Fish mix pellet  
(FMP)**

N content of BBFs



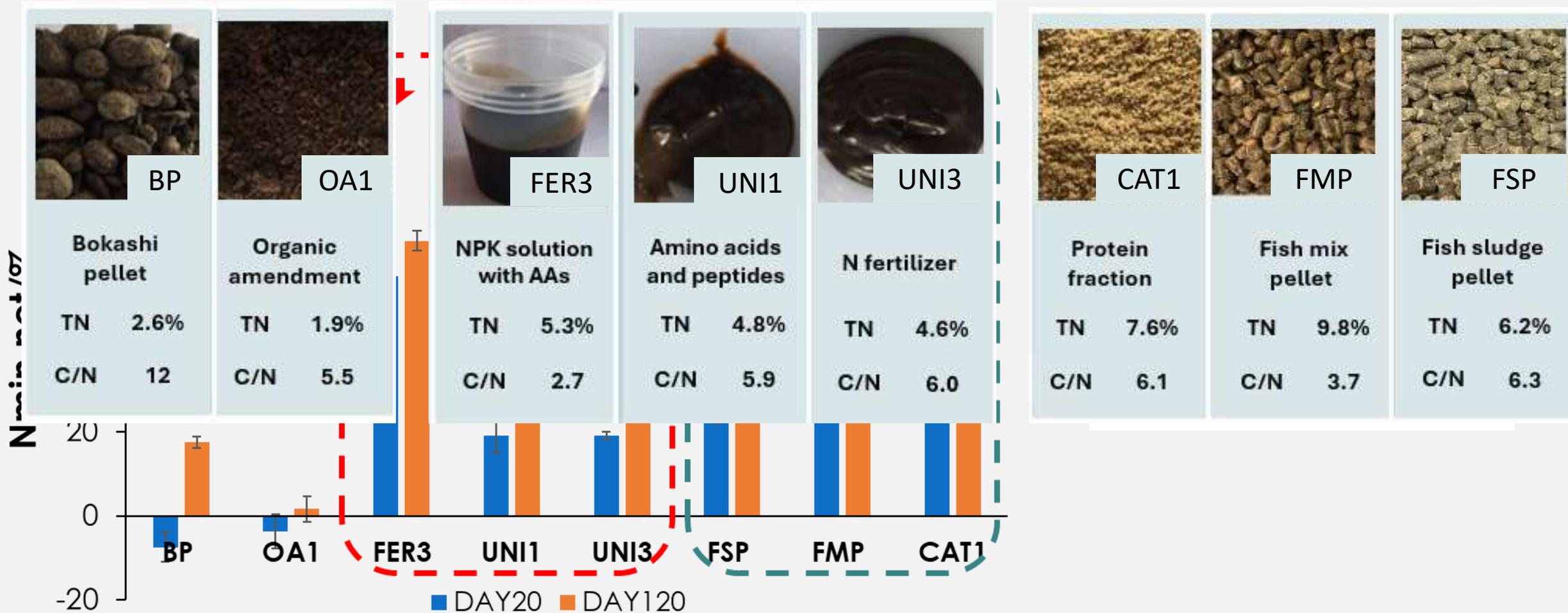
BP: Bokashi pellet  
 OA1: Organic amendment  
 FER3: NPK solution with amino acids  
 UNI1: Amino acids and peptides  
 UNI3: N fertilizer with chitin  
 CAT1: Protein fraction  
 FSP: Fish sludge pellet  
 FMP: Fish mix pellet

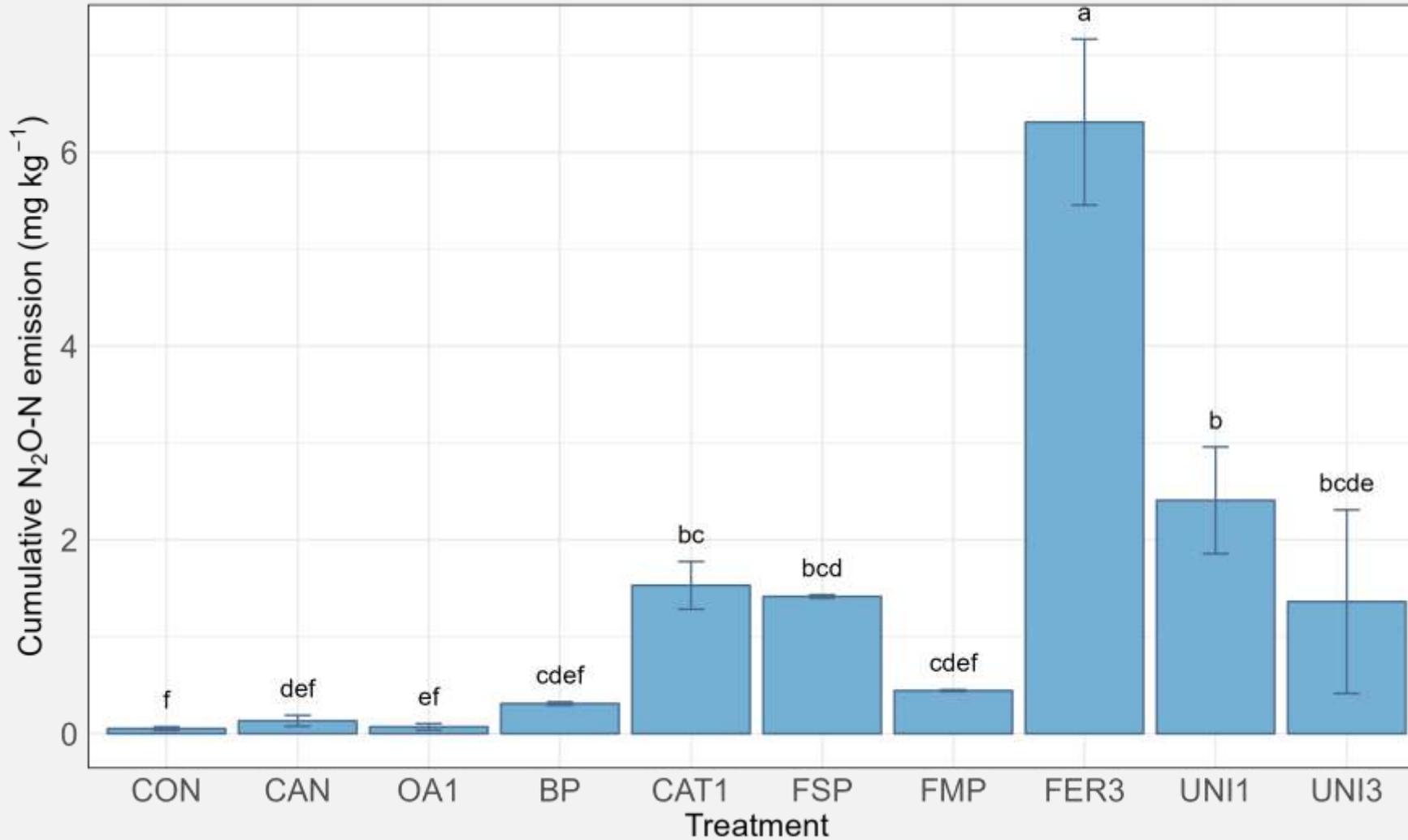


- $N_{rel,net}$  (%): Mineral N released from the fertilizer in the amended soil.
- $$N_{rel,net} = \frac{MN_{fertiliser} - MN_{control}}{N_{applied}}$$

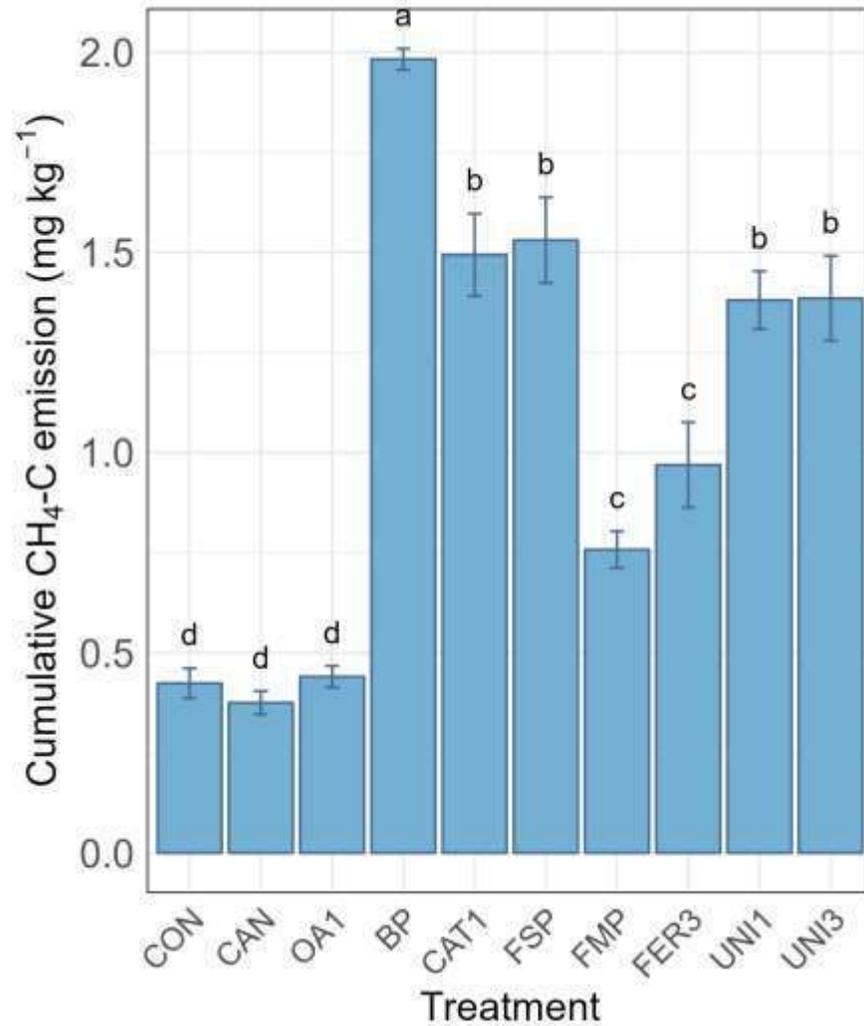
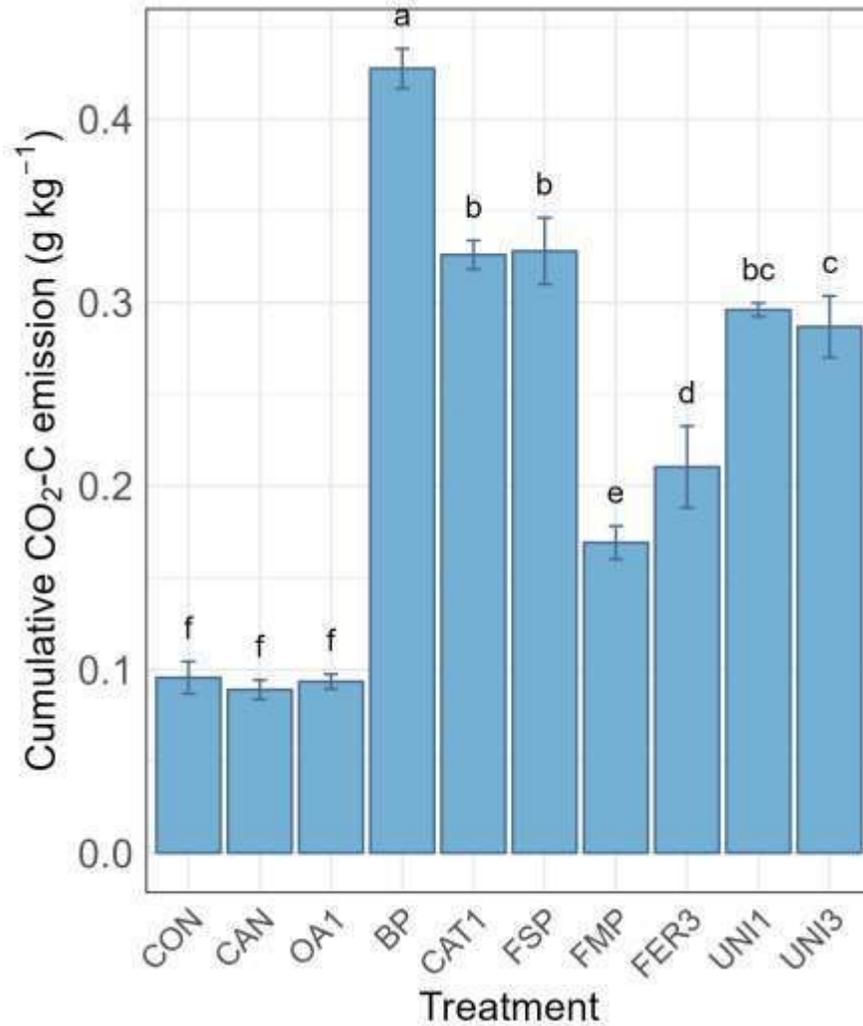
CON: Control (unfertilized)  
 CAN: Calcium ammonium nitrate  
 BP: Bokashi pellet  
 OA1: Organic amendment  
 FER3: NPK solution with amino acids  
 UNI1: Amino acids and peptides  
 UNI3: N fertilizer with chitin  
 CAT1: Protein fraction  
 FSP: Fish sludge pellet  
 FMP: Fish mix pellet

# Nitrogen release and mineralization dynamics



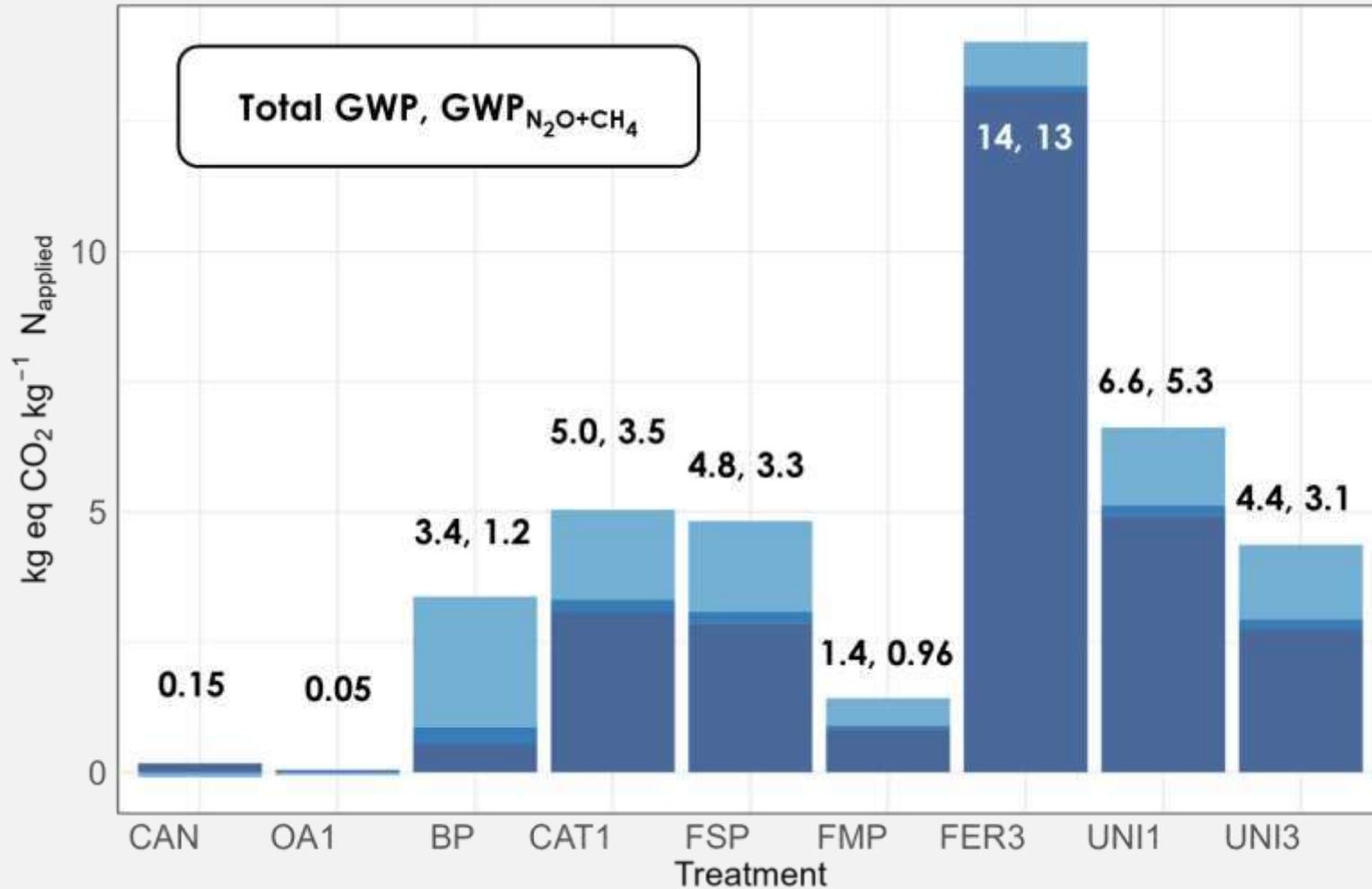


CON: Control (unfertilized)  
CAN: Calcium ammonium nitrate  
BP: Bokashi pellet  
OA1: Organic amendment  
FER3: NPK solution with amino acids  
UNI1: Amino acids and peptides  
UNI3: N fertilizer with chitin  
CAT1: Protein fraction  
FSP: Fish sludge pellet  
FMP: Fish mix pellet



CON: Control (unfertilized)  
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 FER3: NPK solution with amino acids  
 UNI1: Amino acids and peptides  
 UNI3: N fertilizer with chitin  
 CAT1: Protein fraction  
 FSP: Fish sludge pellet  
 FMP: Fish mix pellet

# Global warming potential (associated to the soil application only)

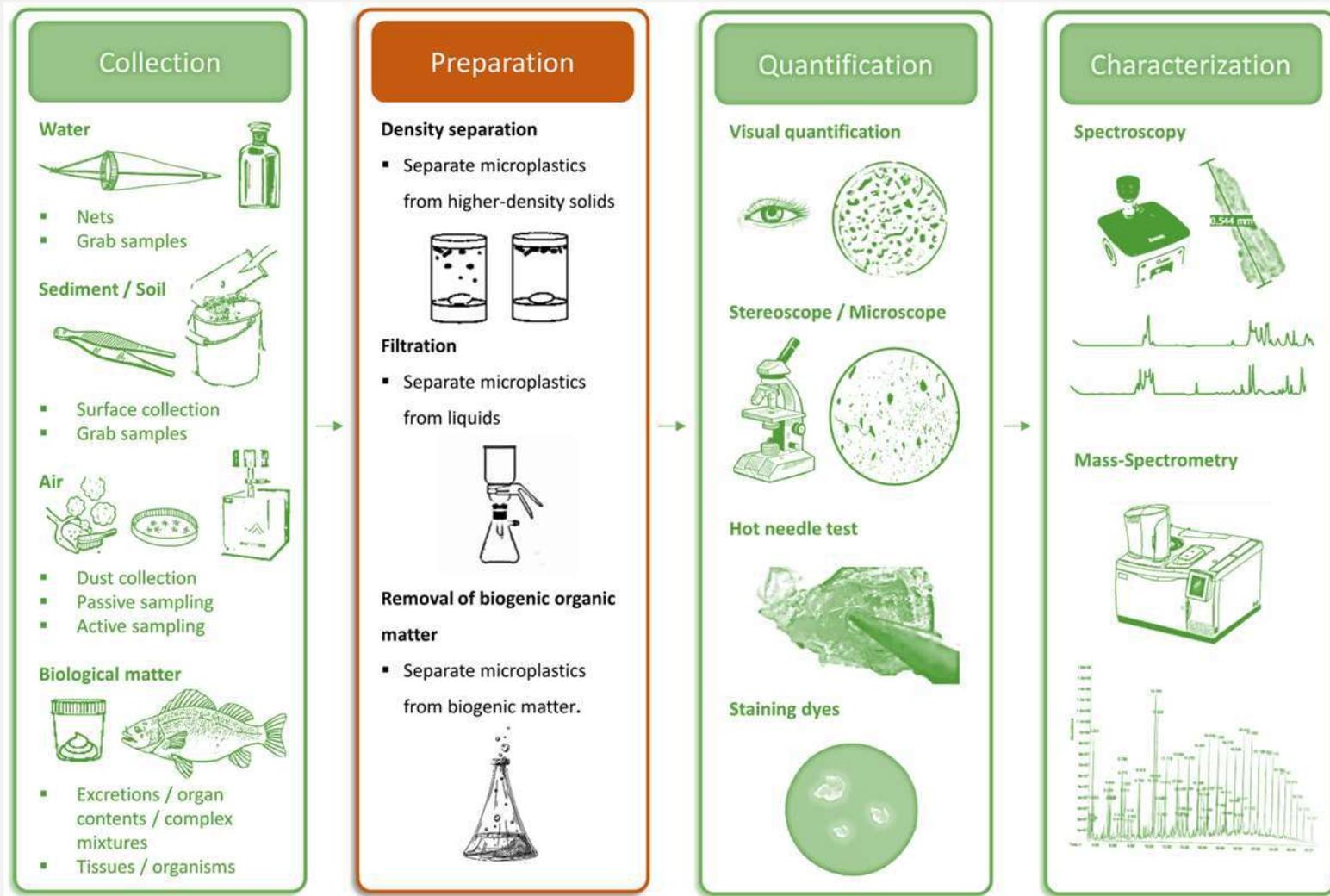


• **GWP:** Assess the warming effects of different greenhouse gases, based on the standardized unit (CO<sub>2</sub> equivalent).

GWP factor:  
 CO<sub>2</sub>: 1  
 CH<sub>4</sub>: 27  
 N<sub>2</sub>O: 273  
 (IPCC,2021)

Gas  
 CO<sub>2</sub>  
 CH<sub>4</sub>  
 N<sub>2</sub>O

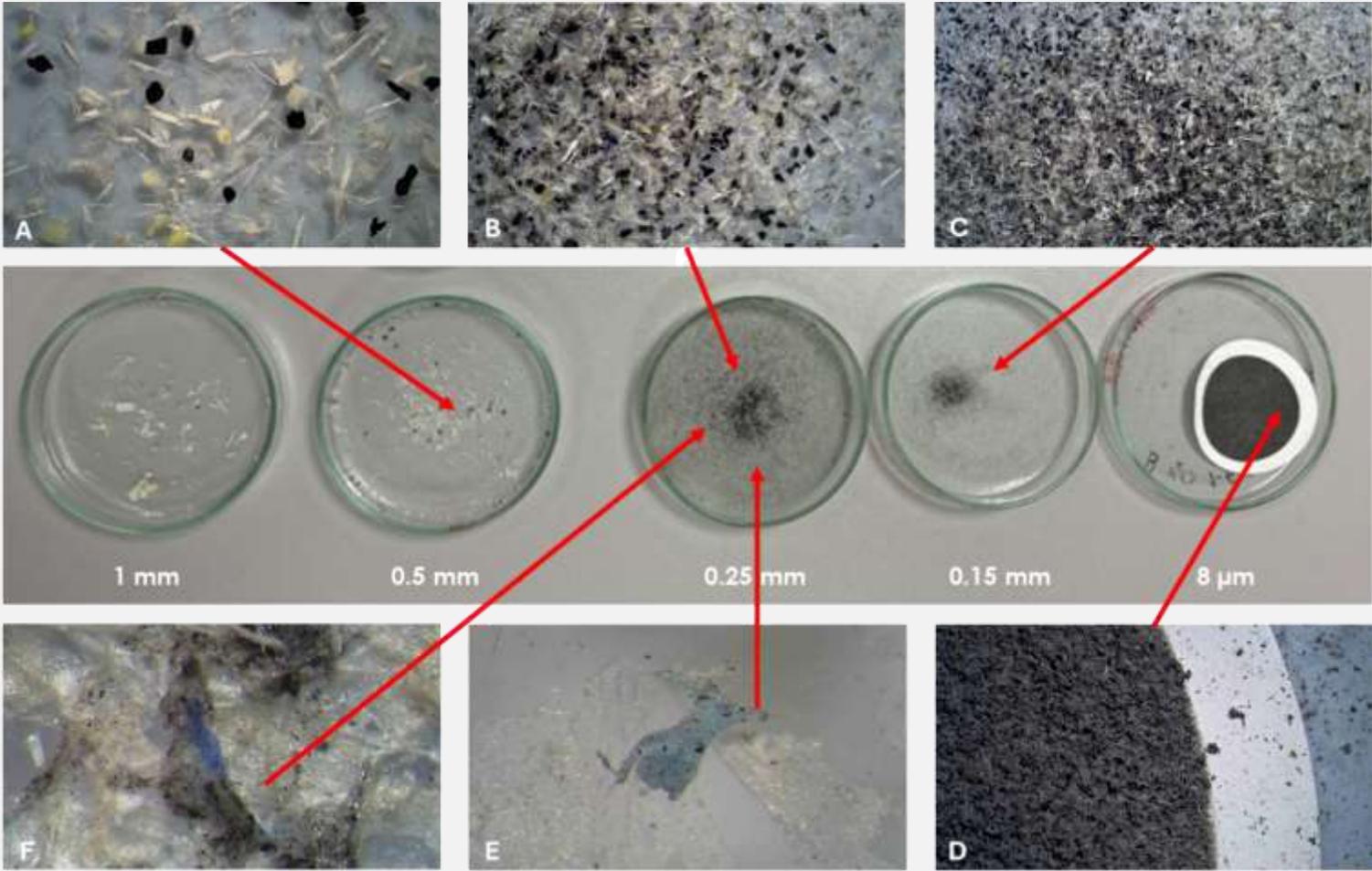
CON: Control (unfertilized)  
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 UNI1: Amino acids and peptides  
 UNI3: N fertilizer with chitin  
 CAT1: Protein fraction  
 FSP: Fish sludge pellet  
 FMP: Fish mix pellet



(Prata JC et al., 2024)

# Microplastics in circular fertilizers







NPK solution with amino acid (FER3)

- 1 brownish, fiber, polyethylene terephthalate (PET)
- 1 black, fragment, PET
- 1 grey, film, polyethylene (PE)
- 1 transparent, fragment, polyamide (PA)

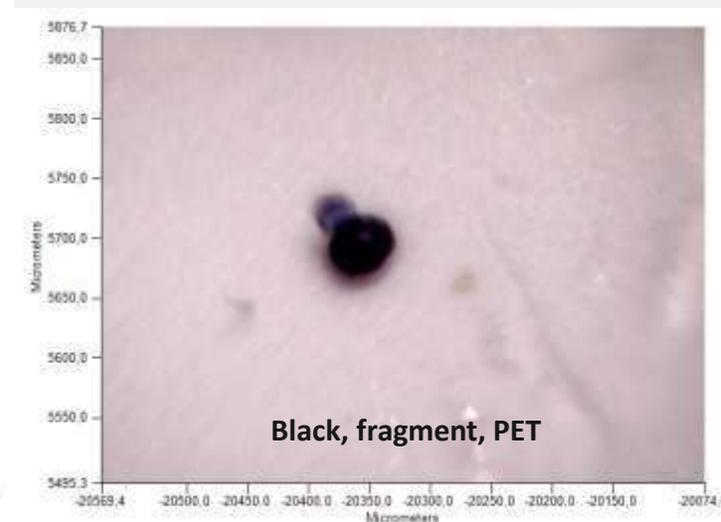


4 items/6 g sample

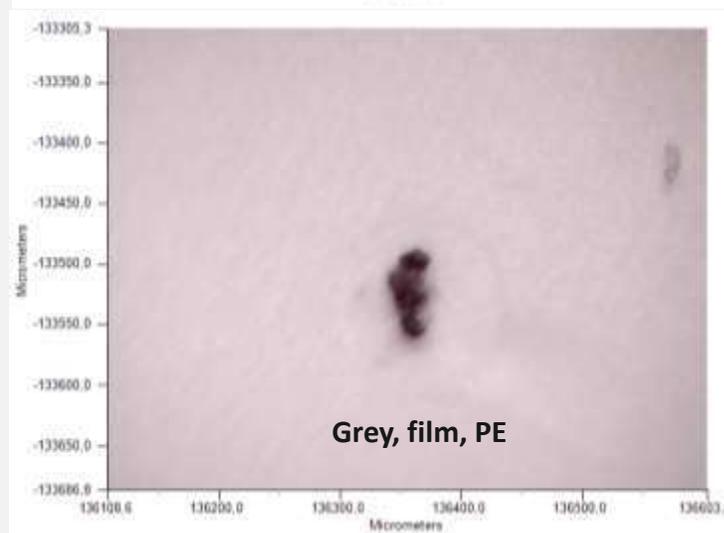
667 items/kg sample



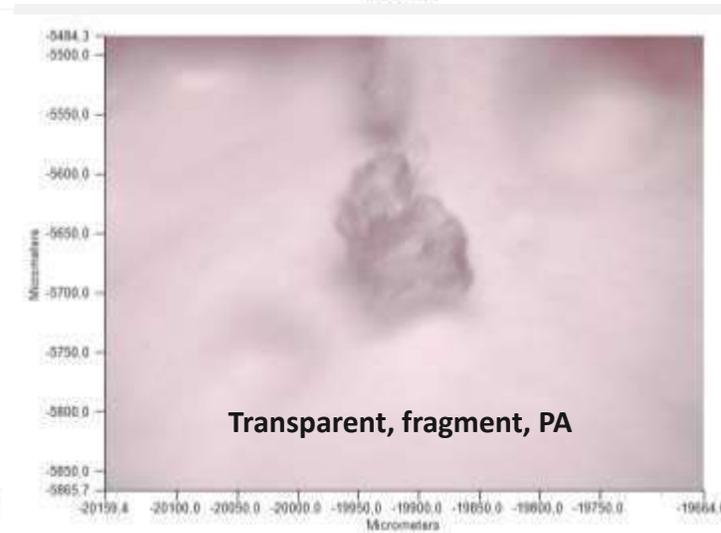
Brownish, fiber, PET



Black, fragment, PET



Grey, film, PE



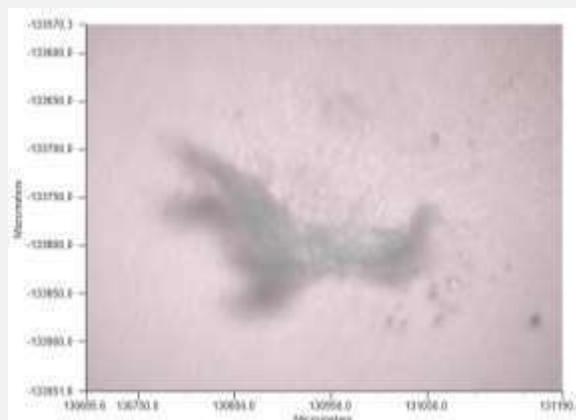
Transparent, fragment, PA



## Microplastics in circular fertilizers



Amino acids and peptides (UNI1)



Light blue, film, PE



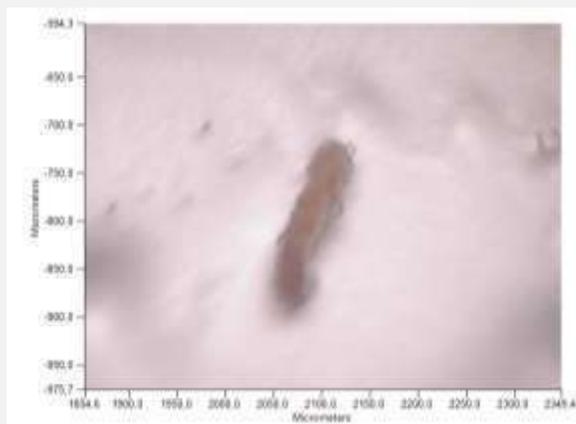
Blue, fragment, PP

- Polyethylene (PE) 23 items
- Polyethylene terephthalate (PET) 1 item
- Polypropylene (PP) 2 items
- Polyamide (PA) 2 items
- Polyurethane (PUR) 1 item



29 items/18g sample

1611 items/kg sample



Brownish, fragment, PUR



Green, fiber, PA



Transparent, fragment, PET

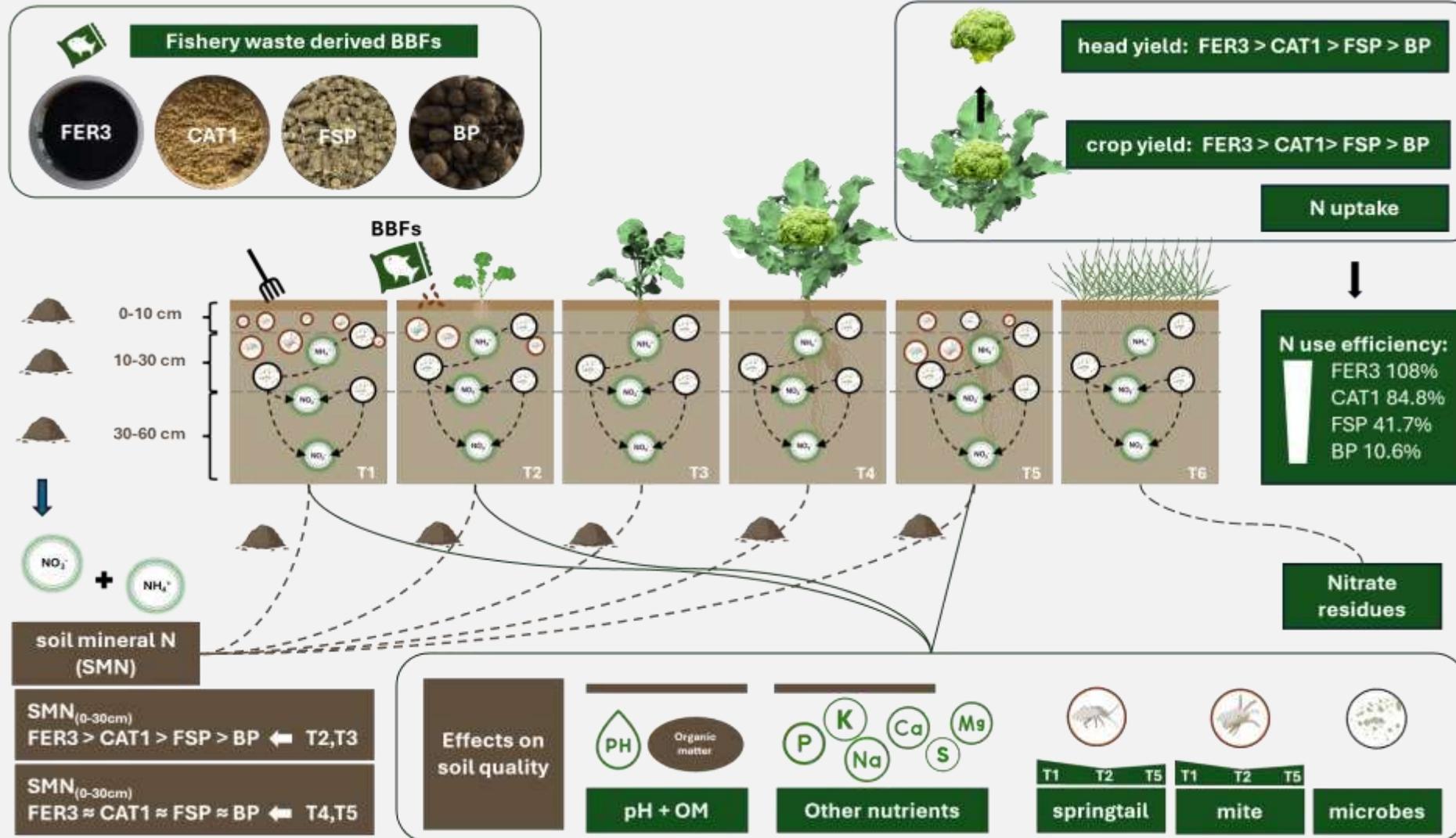


Field trial in Belgium



Field trial in Estonia

# Soil health impacts: field trial in Estonia





These circular fertilizers show high potential for nutrient supply and soil fertility as well as environmental compatibility.

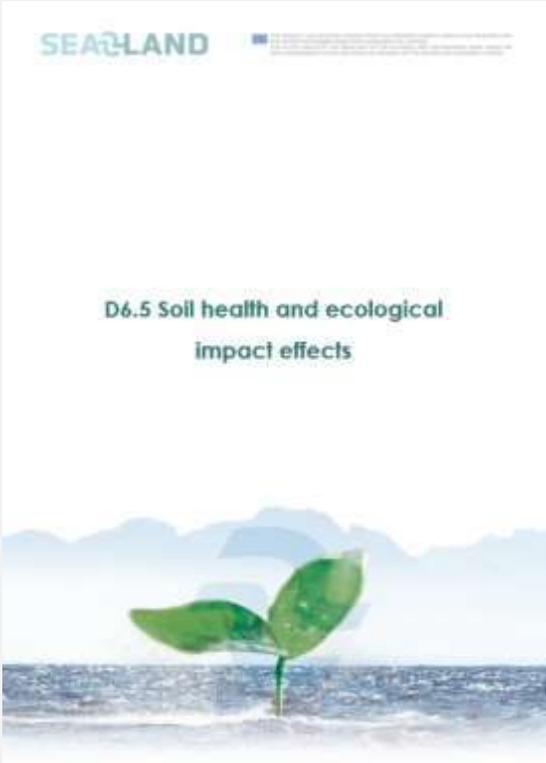
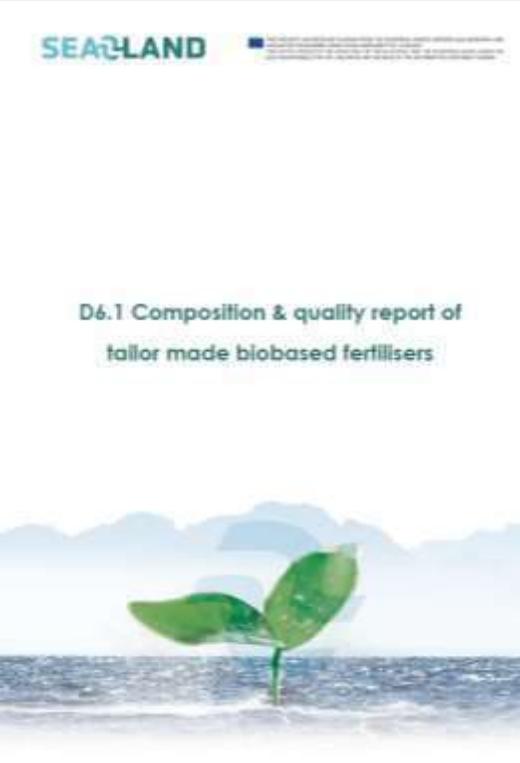
6



Their effects on GHG emission—particularly  $N_2O$  and  $CH_4$  emissions—require further field-based research to ensure sustainable application strategies and minimize their impact on global warming.



The presence of microplastics highlights the need for improved waste processing, careful monitoring and continued research to ensure sustainable agricultural practices.



Journal of Environmental Management 340 (2023) 119266

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**Journal of Environmental Management**

journal homepage: [www.elsevier.com/locate/jemman](http://www.elsevier.com/locate/jemman)

Review

## Nutrient recovery and recycling from fishery waste and by-products

Jingsi Zhang, Çağrı Akyol<sup>a</sup>, Erik Meers

Department of Green Chemistry & Technology, Ghent University, Coupure links 653, 9000 Ghent, Belgium

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**ARTICLE INFO**

**Keywords:**  
 Agronomic performance  
 Circular economy  
 Fertilizing products  
 Fishery waste  
 Nutrient recovery technology  
 Nutrient recycling

**ABSTRACT**

The circular bio-based economy offers great untapped potential for the food industry as possible valuable products and energy can be recovered from food waste. This can promote more sustainable and resilient food systems in Europe in follow-up of the European Commission's Farm to Fork strategy and support the global transition to more sustainable agri-food systems with the common agricultural and fisheries policies. With its high nutrient content, waste and by-products originating from fish and seafood industry (including aquaculture) are one of the most promising candidates to produce alternative fertilizing products which can play a crucial role to replace synthetic mineral fertilizers. Whereas several studies highlighted the opportunities to recover valuable compounds from fishery waste, study towards their potential for the production of fertilizing products is still scarce. This study presents an extensive overview of the characteristics of fishery waste and by-products (i.e., fish processing waste, fish sludge, seafood waste/by-products), the state-of-the-art nutrient recovery technologies and recovered nutrients as fertilizing products from these waste streams. The European Commission has already adopted a revised Fertilizing Products Regulation (EU) 2019/1009 providing opportunities for fertilizing products from various bio-based origins. In frame of this opportunity, we address the quality and safety aspects of the fishery waste-derived fertilizing products under these criteria and highlight possible obstacles on their way to the market in the future. Considering its high nutrient content and vast abundance, fish sludge has a great potential but should be treated/refined before being applied to soil. In addition to the parameter currently regulated, it is crucial to consider the salinity levels of such fertilizing products as well as the possible presence of other micropollutants especially microplastics to warrant their safe use in agriculture. The agronomic performance of fishery waste-derived fertilizers is also compiled and reported in the last section of this review paper, which in most cases perform equally to that of conventional synthetic fertilizers.

Soil & Tillage Research 253 (2025) 106606

Contents lists available at ScienceDirect

**Soil & Tillage Research**

journal homepage: [www.elsevier.com/locate/still](http://www.elsevier.com/locate/still)

Recycling fishery waste into biobased fertilizers: Agronomic performance and soil health impacts

Jingsi Zhang<sup>a,1</sup>, Liina Edesi<sup>b,1</sup>, Tiina Talve<sup>b</sup>, Çağrı Akyol<sup>a,1</sup>, Birgit Koll<sup>c</sup>, Ireene Roman<sup>c</sup>, Merili Toom<sup>b</sup>, Marta Aranguren<sup>d</sup>, Susana Virgel Mentxaka<sup>d</sup>, Annelly Kuu<sup>e</sup>, Stefaan De Neve<sup>f</sup>, Erik Meers<sup>a</sup>

<sup>a</sup> Laboratory for BioResource Recovery (Re-Source), Department of Green Chemistry and Technology, Faculty of Bioscience Engineering, Ghent University, Coupure Links 653, Ghent 9000, Belgium  
<sup>b</sup> Unit of Agrotechnology, Centre of Estonian Rural Research and Knowledge, J. Aamsepa 1, Jõgeva 46309, Estonia  
<sup>c</sup> Department of Plant Breeding, Centre of Estonian Rural Research and Knowledge, J. Aamsepa 1, Jõgeva 46309, Estonia  
<sup>d</sup> NEIKER, Basque Institute for Agricultural Research and Development, Basque Research and Technology Alliance, Parque Científico y Tecnológico de Biskaya, P012, Derio E-48160, Spain  
<sup>e</sup> Institute of Agricultural and Environmental Sciences, Estonian University of Life Sciences, Friedrich Reinhold Kreutzwaldi 1a, Tartu 51014, Estonia  
<sup>f</sup> Research group Soil Fertility and Nutrient Management, Department of Environment, Faculty of Bioscience Engineering, Ghent University, Coupure Links 653, Ghent 9000, Belgium

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**ARTICLE INFO**

**Keywords:**  
 Broccoli yield  
 Field trial  
 Fishery waste  
 Nitrogen use efficiency  
 Soil mineral nitrogen  
 Soil quality

**ABSTRACT**

This study evaluated the agronomic performance and soil impact of biobased fertilizers derived from fishery waste and by-products as circular alternatives to synthetic nitrogen (N) fertilizers in short-term field experiments with broccoli. Four biobased fertilizers — bokashi pellet (BP), nutrient solution with amino acids (NPKA), fish sludge pellet (FSP), and protein fraction (PF) — were obtained from pilot installations across Europe. The evaluation focused on soil mineral N (SMN) dynamics, N use efficiency (NUE), crop yield, and soil biological responses. One week after transplanting and fertilization, SMN levels in the topsoil (0–10 cm) were the highest in the NPKA (253 ± 94 kg ha<sup>-1</sup>) and PF (181 ± 45 kg ha<sup>-1</sup>) treatments, comparable to the mineral fertilizer (MF; 237 ± 5 kg ha<sup>-1</sup>). In contrast, FSP (68 ± 17 kg ha<sup>-1</sup>) and BP (30 ± 11 kg ha<sup>-1</sup>) did not significantly differ from the unfertilized soil (40 ± 5 kg ha<sup>-1</sup>). Early SMN availability showed a strong positive correlation with broccoli yield and N uptake. Crop yields ranged from 8594 to 14,842 kg ha<sup>-1</sup> among the organic treatments, with NPKA and PF performing comparably to MF (14,726 kg ha<sup>-1</sup>) and substantially better than FSP and BP. The control treatment (CON) yielded 9252 kg ha<sup>-1</sup>. NPKA and PF also demonstrated the highest NUE values (108 % and 84.8 %, respectively), with estimated mineral fertilizer equivalents of 79.5 % and 62.7 %. Soil biological activity showed treatment-specific responses. Dehydrogenase activity, microbial biomass carbon, and phospholipid fatty acid profiles in the 0–10 cm soil layer were significantly affected by fertilizer treatments, though most microbial indicators returned to baseline levels post-harvest. Soil fauna responses were variable: Springtail abundance declined under MF, whereas mite populations were more sensitive to organic treatments. Overall, the findings suggest that certain biobased fertilizers, particularly NPKA and PF, can effectively replace mineral N fertilizers, maintaining crop productivity while enhancing soil health indicators. These results support the integration of fish waste-based biobased fertilizers into sustainable agricultural practices.

Last but not least...



# SEALAND



THIS PROJECT HAS RECEIVED FUNDING FROM THE EUROPEAN UNION'S HORIZON 2020 RESEARCH AND INNOVATION PROGRAMME UNDER GRAN AGREEMENT NO 101000402  
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DEGLI STUDI  
DI MILANO

