



D6.1 Composition & quality report of tailor made biobased fertilisers



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Document Summary

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Abstract

The deliverable 6.1 (D6.1) presents the characteristics of 26 potential biobased fertiliser (BBF) products generated in WP3, WP4 and Chile including organic fertilisers, (non-microbial) plant biostimulants, soil improver/growing media and liming material. Standardized analytical methods were used to determine the parameters required by the Regulation (EU) 2019/1009, such as moisture and organic matter content, nutrients, heavy metals and pathogens.

The organic carbon (C_{org}) content of BBF products ranged from 0.05% fresh weight (FW) to 46.54% FW, in which seven liquid BBF products contained more than 5% C_{org} and 12 solid products had more than 15% C_{org} . The BBF products showed high variations with respect to primary nutrients content, i.e., Nitrogen (N), Phosphorus (P) and Potassium (K). The highest total N (TN) content of these products reached up to 11.13% FW (Fer% from Cantabrian Sea Pilot) and extremely low content was found less than 0.01% FW (NRC2 from Freshwater Pilot). Five liquid BBF products with the highest moisture content had the lowest TN content < 2% FW. Six semi-liquid products contained 3.90 - 11.13% FW TN. The P contents of BBF products varied from almost null to 12.51% FW. One liquid ('FER3' from Cantabrian Sea Pilot) and one solid BBF products ('FMP' from North Sea Pilot) have the potential to be applied as straight K organic fertiliser after further processing if needed. The sum content of primary nutrients were between 0.02% FW to 30.86% FW. 18 BBF products were composed of 0.02% FW to 30.86% FW sum N, and oxidised forms of P and K (P_2O_5 and K_2O).

The BBF products also contained varying concentrations of secondary nutrients, Calcium (Ca), Magnesium (Mg), Sodium (Na) and Sulphur (S). The Ca content ranged from 0.07 g/kg FW to 355.71 g/kg FW, Mg from 0.01 g/kg FW to 9.89 g/kg FW, Na from 0.21 g/kg FW to 28.03 g/kg FW, and S from 0.02 g/kg to 66.22 g/kg FW. The iodine (I) is an interesting element from marine sourced raw materials. It was also measured in the BBF products, as they can be potentially applied in the areas lack of iodine. The highest iodine content of 'OA1' from Mediterranean Sea Pilot was 114.31 mg/kg FW, while other products had 0.03 - 15.92 mg/kg FW.

The Cu and Ni of 25 BBF products were within the limit value (50 mg/kg dry weight (DW)). The Zn contents did not exceed the limit value in any of the 23 BBF products. The Pb, As and Hg contents of all products met the limits. The Cd contents did not exceed the limit value 2 mg/kg DW except for one BBF product from Chile. Cr(VI) content of the (liquid) BBF products was also determined below the limit (2 mg/kg DW).

Pathogen analysis showed that only two products ('VER' from Baltic Sea Pilot and 'OA2' from Mediterranean Sea Pilot) exceeded the maximum value of the number of *E. coli*, while the others were pathogen-free. Since VER product meets all the requirements to be qualified as a growing medium/soil improver, it should be pasteurized before being applied to soil.

Finally, the liming material produced from shellfish waste at the Adriatic Sea Pilot met the EU requirements. The potential (non-microbial) plant biostimulants with added value features (e.g., free amino acids) did not exhibit any contaminants, while their biostimulating effects should be further tested.

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Glossary

BBF: Biobased fertiliser

CATAR: CATAR-CRITT Agroresources

D: Deliverable

DM: Dry Matter

DW: Dry Weight

FERTINAGRO: Fertinagro Biotech, S.L.

FW: Fresh weight

HPLC: High Performance Liquid Chromatography

IC: Inorganic Carbon

ICP-MS: inductively Coupled Plasma Mass Spectrometry

ICP-OES: inductively Coupled Plasma Optical Emission

INIA: Instituto de Investigaciones Agropecuarias

NIBIO: Norsk Institutt for Bioekonomi

NUTRI: NUTRILOOP OU

OM: Organic Matter

TC: Total Carbon

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TN: Total Nitrogen

UNIVPM: Università Politecnica Delle Marche

UVIC-UCC: Universitat de Vic – Universitat Central de Catalunya

WP: Work Package



1 Introduction

Waste and/or by-products from fishery, fish and seafood processing and aquaculture often has a high content of nutrients needed for plant growth. They are therefore some of the most promising candidates for alternative fertilising products which can play a crucial role in replacing mineral fertilisers.

This document presents the results of Task 6.1 characterization of the 26 fertilising products generated from the pilot areas of Baltic, Cantabrian and Adriatic in WP3, the pilots from North Sea, Atlantic, Mediterranean and Freshwater areas in WP4 and additional BBF products from Chile. Physical-chemical characteristics of the BBF samples were determined by standardized methods. The quality and safety of potential BBF products were assessed according to the parameters in the Regulation (EU) 2019/1009, including nutrients and pollutants contents. The qualified BBFs were selected for further trials in WP5, WP6 and WP7.

2 Materials and methods

2.1 Biobased fertilisers received from WP3, WP4 and Chile

Biobased fertilisers (BBFs) were collected from seven pilots of WP3 and WP4 and from the partner INIA in Chile. A total of 26 samples were obtained from the WP3 pilots on fishing industry and the WP4 pilots on aquaculture industry, including 12 BBF products from WP3, 10 BBF products from WP4, and additional 4 products from Chile (Table 1). The partners initially proposed five BBF types as follows: organic fertiliser (n. 16), foliar fertiliser (n. 1), plant biostimulant (n. 7), soil improver/growing media (n. 1) and liming material (n. 1).

2.2 Analytical methods

Physical-chemical composition

The physical and chemical characterization of the BBF products were performed in the laboratories of Ghent University, Belgium. All products were analysed in triplicates. Hexavalent chromium (Cr(VI)) and biuret were analysed by LUFA Nord-West, Germany. Free amino acids in the Cantabrian Sea, Atlantic Sea and Adriatic Sea Pilots were analysed by Fertinagro, CATAR, and UMIL, respectively. The pathogen contents of the BBF products were determined by UMIL.

Dry matter content (DM) was calculated after drying samples in the oven at 105 °C until constant weight (ISO 18134-2:2017). Moisture content (%) was calculated by $1 - \text{DM}\%$.

Ash content was determined by introducing the samples in the calcination furnace at 550 °C for 4 hours (ISO 18122:2015). Organic matter (OM) content was calculated as: $1 - \text{ash}\%$.

pH values were determined by a pH-meter after water extraction (ratio 1/5 w/w) and 16 hours standing (ISO 2917:1999). Electrical conductivity (EC) was determined by a conductivity meter after water extraction (ratio 1:5 w/w), 1 hour shaking and filtration (EN 13038, 2011).

Total carbon (TC) and inorganic carbon (IC) was determined by CN Elementary Analyzer (Primacs100, Skalar, the Netherlands). Total organic carbon was calculated as $\text{TC}\% - \text{IC}\%$.

Total nitrogen (TN) was determined by Kjeldahl method. Ammonium nitrogen ($\text{NH}_4^+ - \text{N}$) and nitrate nitrogen ($\text{NO}_3 - \text{N}$) were extracted by 1 mol/l potassium chloride solution and analyzed on auto-flow analyzer (Chemlab System 4, Skalar, the Netherlands).

Macronutrients, phosphorous (P), sulphur (S), sodium (Na), magnesium (Mg) and calcium (Ca) and potassium (K), and heavy metals were determined by ICP-OES after microwave digestion with nitric acid (EPA, 2007). As and Hg were analysed using ICP-MS after microwave digestion with nitric acid and reverse aqua regia, respectively.

Iodine (I) was extracted by Tetramethylammonium hydroxide (TMAH) and determined via Inductively Coupled Plasma Mass Spectrometry (ICP-MS) (Cakmak et al., 2020).

The plant available P was extracted with an ammonium lactate-acetic acid buffer and determined on using Inductively Coupled Plasma Optical Emission (ICP-OES) (MEN 5793:2008).

Hexavalent chromium, Cr(VI), was analysed by Ion Chromatography With Spectrophotometric Detection (DIN EN 16318:2016-07).

Biuret contents were determined by High Performance Liquid Chromatography (HPLC) based on the VDLUFA method book (VDLUFA-Verlag, 1995).

Free amino acids in the potential biostimulants from Cantabrian Sea Pilot were detected according to the methods described in Shahbazi and Hasheminasab (2022) and Alarcón-Flores et al. (2010), respectively. Free amino acid in the biostimulants in the Atlantic Sea Pilot were detected according to the French Directive 98/64/Ce De La

Commission. Finally, free amino acids in the hydrolysate of UNIVPM was measured according to the method described in D3.5.

The neutralizing value of the liming material was determined by titrimetric method (ISO 20978:2020). The size distribution of the liming material was determined by dry sieving (EN 12948:2010). The reactivity of the liming material was determined by manual titration (BS EN 13971:2008).

Pathogens

Salmonella (absent/present 25g⁻¹) contamination was determined according to horizontal method for the detection, enumeration and serotyping of *Salmonella* (EVS-EN ISO 6579-1). *Escherichia coli* (CFU g⁻¹) contamination was determined according to horizontal method for the enumeration of beta-glucuronidase-positive *Escherichia coli* (EVS-ISO 16649-2).

2.3 Calculations

The requirements of certain elements are expressed in oxidised forms in the Regulation (EU) 2009/1009. However, the analytical analysis for these elements are assessed based on the presence of the element form. The following conversion factors shall be used to calculate the content of oxidised forms (Eq. 1-6).

$$\text{Phosphorus (P)} = \text{Phosphorus Pentoxide (P}_2\text{O}_5) \times 0.436 \quad (\text{Eq. 1})$$

$$\text{Potassium (K)} = \text{Potassium Oxide (K}_2\text{O)} \times 0.830 \quad (\text{Eq. 2})$$

$$\text{Calcium (Ca)} = \text{Calcium Oxide (CaO)} \times 0.715 \quad (\text{Eq. 3})$$

$$\text{Magnesium (Mg)} = \text{Magnesium Oxide (MgO)} \times 0.603 \quad (\text{Eq. 4})$$

$$\text{Sodium (Na)} = \text{Sodium Oxide (Na}_2\text{O)} \times 0.742 \quad (\text{Eq. 5})$$

$$\text{Sulphur (S)} = \text{Sulphur Trioxide (SO}_3) \times 0.400 \quad (\text{Eq. 6})$$

Table 1 Initially proposed BBF products, form types and producers.

Task	Area	Lead	BBF product	Code	Form	Proposed BBF type by the partners before analyses
3.1	Baltic Sea	NUTRI	1) Foliar fertiliser	FS	liquid(l)	Foliar fertiliser
			2) Bokashi pellet	BP	Solid(s)	Organic fertiliser
			3) Vermicompost and/or substrate	VER	s	Organic fertiliser
3.2	Cantabrian Sea	FERTINAGRO	1) Amino acids, organic matter and humic extract	FER1	s	Plant biostimulant
			2) Foliar fertiliser with N and amino acids	FER2	l	Plant biostimulant
			3) NPK solution with amino acids	FER3	l	Plant biostimulant
			4) Foliar fertiliser with amino acid, humic extract, organic matter	FER4	l	Plant biostimulant
			5) Fertiliser with humic acids	FER5	l	Plant biostimulant
3.3	Adriatic Sea	UNIVPM	1) Hydrolysates	UNI1	l	Plant biostimulant
			2) Biochar-compost composite	UNI2	s	Growing media/soil improver
			3) Chitin-rich fertiliser	UNI3	l	Organic fertiliser
			4) CaCO ₃	UNI4	s	Liming material
4.1	North Sea	NIBIO	1) Fish sludge pelleted fertiliser	FSP	s	Organic fertiliser
			2) Fish mix pelleted fertiliser	FMP	s	Organic fertiliser
4.2	Atlantic Sea	CATAR	1) Protein fraction	CAT1	s	Organic fertiliser
			2) Amino acids and peptides	CAT2	l	Plant biostimulant
			3) Protein fraction_upgraded	CAT3	s	Organic fertiliser
			4) Amino acids and peptides_upgraded	CAT4	l	Plant biostimulant
4.3	Mediterranean Sea	UVIC	1) Nutrient-rich concentrate	NRC1	l	Organic fertiliser
			2) Organic amendment	OA1	s	Organic fertiliser
4.4	Freshwater	UVIC	1) Nutrient-rich concentrate	NRC2	l	Organic fertiliser
			2) Organic amendment	OA2	s	Organic fertiliser
Chile	Chilean Sea	INIA	1) Peptone	Pep	s	Organic fertiliser
			2) Salmon bones flour	SBF	s	Organic fertiliser
			3) Dried fish sludge	DFS	s	Organic fertiliser
			4) Compost	Com	s	Organic fertiliser

3 Results and discussion

3.1 Characterization of the BBF products

The basic physical and chemical characteristics of 26 BBF products are given in Table 2. The BBF samples contain 15 solid products and 11 liquid products. The pH of the BBF products varied from 2.89 to 8.10, while the EC of these products were mostly between 3.88 to 27.75 mS/cm. The liquid BBFs can be grouped into two: i) five nutrient rich liquid BBFs from NUTRI, CATAR AND UVIC with high moisture contents, ranging from 88.86% to 99.83%, and ii) six semi-liquid BBFs with lower moisture contents (53.64 – 65.54%) from FERTIAGRO and UNIVPM. The only liming material derived from mussel shells has lowest OM content and was composed of 97.86% DM ash. The others were composed of 20.74 – 95.01% OM in the DM basis. Nutrient contents are shown in Table 3 and Table 4.

Table 2 Basic parameters of biobased fertilisers (expressed as mean \pm standard deviation).

Lead	Code	pH	EC/(mS/cm; * μ S/cm)	Moisture/%	Dry matter/ %	OM/% DM	Ash/% DM
NUTRI	FS	3.88 \pm 0.02	10.61 \pm 0.06	97.44 \pm 0.01	2.56 \pm 0.01	71.46 \pm 0.16	28.54 \pm 0.16
	BP	7.21 \pm 0.04	5.87 \pm 0.22	9.35 \pm 0.17	90.65 \pm 0.17	61.85 \pm 1.28	38.15 \pm 1.28
	VER	7.22 \pm 0.06	941.3 \pm 0.98*	54.46 \pm 0.28	45.54 \pm 0.28	33.17 \pm 0.76	66.83 \pm 0.76
FERTIN AGRO	FER1	3.83 \pm 0.01	24.11 \pm 0.37	10.78 \pm 0.19	89.22 \pm 0.19	95.01 \pm 0.04	4.99 \pm 0.04
	FER2	6.29 \pm 0.01	11.22 \pm 0.31	64.45 \pm 0.49	35.55 \pm 0.49	89.92 \pm 0.18	10.08 \pm 0.18
	FER3	4.82 \pm 0.02	18.71 \pm 0.03	65.54 \pm 0.16	34.46 \pm 0.16	78.78 \pm 0.17	21.22 \pm 0.17
	FER4	4.56 \pm 0.01	14.65 \pm 0.04	63.34 \pm 0.1	36.66 \pm 0.10	94.49 \pm 0.03	5.51 \pm 0.03
	FER5	4.28 \pm 0.04	17.48 \pm 0.23	53.64 \pm 0.28	46.36 \pm 0.28	93.18 \pm 0.06	6.82 \pm 0.06
UNIVP M	UNI1	5.78 \pm 0.01	21.19 \pm 0.23	57.88 \pm 1.71	42.12 \pm 1.71	82.46 \pm 0.21	17.54 \pm 0.21
	UNI2	7.04 \pm 0.01	7.98 \pm 0.50	5.41 \pm 0.07	94.59 \pm 0.07	77.32 \pm 0.14	22.68 \pm 0.14
	UNI3	5.80 \pm 0.01	20.93 \pm 0.25	57.68 \pm 0.17	42.32 \pm 0.17	82.91 \pm 0.11	17.09 \pm 0.11
	UNI4	8.10 \pm 0.11	410.3 \pm 4.35*	0.34 \pm 0.04	99.66 \pm 0.04	2.14 \pm 0.19	97.86 \pm 0.19
NIBIO	FSP	6.15 \pm 0.01	8.32 \pm 0.6	5.60 \pm 0.23	94.4 \pm 0.23	82.5 \pm 0.39	17.5 \pm 0.39
	FMP	6.17 \pm 0.03	22.19 \pm 0.14	5.49 \pm 0.11	94.51 \pm 0.11	71.10 \pm 0.72	28.9 \pm 0.72
CATAR	CAT1	6.05 \pm 0.02	4.37 \pm 0.36	1.94 \pm 0.24	98.06 \pm 0.24	83.82 \pm 0.74	16.18 \pm 0.74
	CAT2	3.03 \pm 0.03	3.88 \pm 0.02	88.86 \pm 0.33	11.14 \pm 0.33	93.48 \pm 0.46	6.52 \pm 0.46
	CAT3	6.36 \pm 0.02	7.58 \pm 0.12	3.54 \pm 0.05	96.46 \pm 0.05	73.39 \pm 0.91	26.61 \pm 0.91
	CAT4	2.89 \pm 0.01	5.19 \pm 0.02	91.59 \pm 0.07	8.41 \pm 0.07	84.52 \pm 0.33	15.48 \pm 0.33
UVIC	NRC1	7.60 \pm 0.01	9.74 \pm 0.09	99.83 \pm 0.01	0.17 \pm 0.01	20.80 \pm 0.17	79.2 \pm 0.17
	OA1	7.98 \pm 0.02	7.06 \pm 0.15	53.97 \pm 0.24	46.03 \pm 0.24	42.30 \pm 0.33	57.7 \pm 0.33
UVIC	NRC2	7.45 \pm 0.01	541.5 \pm 6.32*	96.41 \pm 0.05	3.59 \pm 0.05	20.74 \pm 8.67	79.26 \pm 8.67
	OA2	7.59 \pm 0.03	5.49 \pm 0.13	51.06 \pm 0.58	48.94 \pm 0.58	78.60 \pm 1.31	21.4 \pm 1.31
INIA	Pep	4.86 \pm 0.05	27.75 \pm 0.04	9.16 \pm 0.34	90.84 \pm 0.34	83.59 \pm 0.04	16.41 \pm 0.04
	SBF	6.59 \pm 0.02	8.22 \pm 0.27	8.58 \pm 1.94	91.42 \pm 1.94	56.07 \pm 0.13	43.93 \pm 0.13
	DFS	5.84 \pm 0.01	4.73 \pm 0.02	2.23 \pm 0.05	97.77 \pm 0.05	58.45 \pm 0.31	41.55 \pm 0.31
	Com	7.30 \pm 0.07	9.89 \pm 0.56	12.35 \pm 1.97	87.65 \pm 1.97	37.99 \pm 2.4	62.01 \pm 2.4

Table 3 Macronutrients and mineral forms of N and P in the biobased fertilisers (expressed as mean \pm standard deviation by mass/FW).

Task	Area	Lead	Code	Form	TN/%	NH ₄ ⁺ -N/ (g/kg)	NO ₃ ⁻ -N/ (g/kg)	P/(g/kg)	Plant available P/(g/kg)	K/(g/kg)
3.1	Baltic Sea	NUTRI	FS	l	0.12 \pm 0.00	0.27 \pm 0.01	0.007 \pm 0.002	0.70 \pm 0.02	0.43 \pm 0.00	1.32 \pm 0.01
			BP	s	2.63 \pm 0.09	0.38 \pm 0.02	<0.002	10.45 \pm 3.80	5.50 \pm 0.19	19.09 \pm 1.68
			VER	s	0.89 \pm 0.06	0.11 \pm 0.00	<0.002	2.65 \pm 0.05	0.86 \pm 0.03	9.68 \pm 0.53
3.2	Cantabrian Sea	FERTINAGRO	FER1	s	7.14 \pm 0.15	12.00 \pm 0.29	<0.002	1.02 \pm 0.01	1.05 \pm 0.02*	3.08 \pm 0.08
			FER2	l	4.34 \pm 0.24	2.23 \pm 0.02	<0.002	3.71 \pm 0.08	3.55 \pm 0.09	4.38 \pm 0.04
			FER3	l	5.31 \pm 0.10	2.56 \pm 0.01	<0.002	15.93 \pm 1.11	13.72 \pm 0.03	22.38 \pm 1.89
			FER4	l	3.90 \pm 0.08	4.74 \pm 0.12	<0.002	2.93 \pm 0.05	2.59 \pm 0.05	3.29 \pm 0.04
			FER5	l	11.13 \pm 0.19	8.81 \pm 0.37	<0.002	13.33 \pm 0.35	11.76 \pm 0.12	1.88 \pm 0.11
3.3	Adriatic Sea	UNIVPM	UNI1	l	4.82 \pm 0.17	10.95 \pm 0.09	<0.002	3.25 \pm 0.09	3.22 \pm 0.03	6.08 \pm 0.11
			UNI2	s	3.72 \pm 0.08	4.79 \pm 0.16	<0.002	7.09 \pm 0.96	5.92 \pm 0.31	10.93 \pm 1.42
			UNI3	l	4.62 \pm 0.03	10.48 \pm 0.09	<0.002	3.17 \pm 0.04	3.25 \pm 0.10*	6.06 \pm 0.06
			UNI4	s	0.18 \pm 0.03	0.01 \pm 0.00	<0.002	0.15 \pm 0.02	0.031 \pm 0.003	0.09 \pm 0.01
4.1	North Sea	NIBIO	FSP	s	6.19 \pm 0.07	0.62 \pm 0.06	<0.002	27.42 \pm 4.51	13.88 \pm 0.13	14.62 \pm 2.04
			FMP	s	9.77 \pm 0.22	0.38 \pm 0.05	0.007 \pm 0.002	20.23 \pm 1.70	14.34 \pm 0.24	56.01 \pm 0.74
4.2	Atlantic Sea	CATAR	CAT1	s	7.62 \pm 0.72	0.34 \pm 0.02	<0.002	30.89 \pm 0.71	24.74 \pm 0.92	6.15 \pm 0.11
			CAT2	l	1.48 \pm 0.03	0.28 \pm 0.01	<0.002	0.76 \pm 0.03	0.71 \pm 0.01	2.04 \pm 0.11
			CAT3	s	8.14 \pm 0.17	0.07 \pm 0.00	0.013 \pm 0.002	24.69 \pm 10.54	n.m**	4.44 \pm 0.10
			CAT4	l	1.12 \pm 0.00	0.21 \pm 0.00	0.005 \pm 0.002	0.77 \pm 0.02	n.m	2.42 \pm 0.05
4.3	Mediterranean Sea	UVIC	NRC1	l	0.098 \pm 0.04	0.58 \pm 0.01	<0.002	0.02 \pm 0.00	0.0068 \pm 0.00	0.19 \pm 0.00
			OA1	s	1.89 \pm 0.08	2.77 \pm 0.12	<0.002	125.07 \pm 13.20	18.81 \pm 0.08	2.37 \pm 0.09
4.4	Freshwater	UVIC	NRC2	l	0.009 \pm 0.00	0.07 \pm 0.00	<0.002	0.01 \pm 0.00	0.0015 \pm 0.0002	0.04 \pm 0.00
			OA2	s	3.46 \pm 0.11	7.09 \pm 0.15	<0.002	14.99 \pm 1.31	3.46 \pm 0.31	9.35 \pm 0.30
Chile	Chilean Sea	INIA	Pep	s	10.77 \pm 0.07	3.42 \pm 0.08	<0.002	14.89 \pm 0.05	13.01 \pm 0.31	14.33 \pm 0.15
			SBF	s	7.80 \pm 0.13	1.76 \pm 0.06	<0.002	76.92 \pm 1.40	38.72 \pm 1.35	4.26 \pm 0.12
			DFS	s	3.59 \pm 0.00	0.60 \pm 0.01	<0.002	58.21 \pm 0.80	21.71 \pm 1.09	1.29 \pm 0.48
			Com	s	1.49 \pm 0.34	0.71 \pm 0.09	0.37 \pm 0.05	6.78 \pm 0.54	2.24 \pm 0.17	4.66 \pm 0.16

*The P of the products can be 100% mobile in the soil.

**n.m: not measured (due to later production of the products)

Table 4 Secondary nutrients in biobased fertilisers (expressed as mean \pm standard deviation by mass/FW).

Task	Area	Lead	Code	Form	Ca/(g/kg)	Mg/(g/kg)	Na/(g/kg)	S/(g/kg)
3.1	Baltic Sea	NUTRI	FS	l	0.16 \pm 0.00	0.09 \pm 0.00	0.35 \pm 0.00	0.23 \pm 0.01
			BP	s	66.04 \pm 5.17	6.19 \pm 0.83	13.58 \pm 0.64	2.52 \pm 0.11
			VER	s	24.44 \pm 1.84	4.00 \pm 0.21	10.11 \pm 0.65	1.60 \pm 0.09
3.2	Cantabria n Sea	FERTINA GRO	FER 1	s	2.14 \pm 0.05	0.83 \pm 0.01	8.17 \pm 0.22	66.22 \pm 3.48
			FER 2	l	0.11 \pm 0.00	0.18 \pm 0.00	9.27 \pm 0.17	4.80 \pm 0.07
			FER 3	l	0.75 \pm 0.12	0.47 \pm 0.08	2.64 \pm 0.29	7.28 \pm 0.52
			FER 4	l	0.67 \pm 0.03	0.23 \pm 0.01	2.10 \pm 0.06	18.78 \pm 0.34
			FER 5	l	0.46 \pm 0.03	0.23 \pm 0.02	0.44 \pm 0.02	30.48 \pm 0.71
3.3	Adriatic Sea	UNIVPM	UNI 1	l	4.59 \pm 0.05	1.41 \pm 0.07	9.69 \pm 0.44	4.41 \pm 0.06
			UNI 2	s	24.19 \pm 0.94	2.56 \pm 0.35	7.52 \pm 1.10	3.95 \pm 0.29
			UNI 3	l	4.52 \pm 0.01	1.37 \pm 0.02	9.33 \pm 0.72	4.53 \pm 0.01
			UNI 4	s	355.71 \pm 6.47	0.25 \pm 0.02	4.70 \pm 0.03	0.75 \pm 0.03
4.1	North Sea	NIBIO	FSP	s	49.20 \pm 7.11	5.36 \pm 0.91	15.78 \pm 1.51	8.67 \pm 1.88
			FMP	s	48.25 \pm 1.35	3.48 \pm 0.14	14.07 \pm 0.14	28.65 \pm 1.71
4.2	Atlantic Sea	CATAR	CAT 1	s	52.62 \pm 1.30	1.32 \pm 0.03	7.08 \pm 0.62	5.13 \pm 0.09
			CAT 2	l	0.07 \pm 0.00	0.06 \pm 0.00	1.37 \pm 0.18	1.03 \pm 0.04
			CAT 3	s	97.95 \pm 15.41	1.95 \pm 0.35	5.22 \pm 0.23	5.79 \pm 0.32
			CAT 4	l	0.15 \pm 0.00	0.22 \pm 0.00	2.52 \pm 0.05	0.96 \pm 0.03
4.3	Mediterran ean Sea	UVIC	NR C1	l	0.18 \pm 0.01	0.58 \pm 0.01	4.52 \pm 0.08	0.24 \pm 0.00
			OA 1	s	168.91 \pm 4.85	9.89 \pm 0.50	20.45 \pm 0.60	10.07 \pm 0.90
4.4	Freshwater	UVIC	NR C2	l	0.07 \pm 0.00	0.01 \pm 0.00	0.21 \pm 0.00	0.02 \pm 0.00
			OA 2	s	22.32 \pm 3.68	2.61 \pm 0.13	11.09 \pm 0.62	5.25 \pm 0.13
Chi le	Chilean Sea	INIA	Pep	s	15.72 \pm 0.12	3.41 \pm 0.01	28.03 \pm 0.50	8.71 \pm 0.04
			SBF	s	148.15 \pm 3.54	3.37 \pm 0.05	8.74 \pm 0.26	4.28 \pm 0.10

D6.1

Composition & quality report of tailor made biobased fertilisers

			DFS	s	127.21 ± 1.13	2.64 ± 0.02	3.55 ± 1.13	3.53 ± 0.05
			Com	s	156.87 ± 0.97	1.90 ± 0.01	11.60 ± 0.49	3.20 ± 0.07



3.2 Quality assessment of BBF products

The Regulation (EU) 2019/1009 sets out rules for EU fertilising products carrying the CE marking, including requirements for: maximum levels of contaminants and pathogens; minimum content of nutrients and other relevant characteristics depending on the category of the product. Although BBFs originated from fishery waste and by-products have not yet been included in the Regulation, here we assessed their potential quality and safety according to the limit values given in the Regulation (EU) 2019/1009.

Different product functions warrant different product safety and quality requirements adapted to their different intended uses. The Regulation enables the market for new and innovative organic fertilisers by defining the conditions under which these can access the EU Single Market. EU fertilising products are divided into different product function categories (PFCs), which should each be subject to specific safety and quality requirements adapted to their different intended uses. According to the Regulation, EU fertilising products are divided into seven product function categories (PFCs). The BBF products classified as fertilisers (PFC 1) must meet certain criteria, such as primary macronutrients (N, P, K), secondary macronutrients (Ca, Mg, Na, S), micronutrients (e.g., Cu, Zn) and organic carbon (C_{org}). Fertilisers have 3 sub categories, organic fertiliser, organo-mineral fertiliser and Inorganic fertiliser. In our study, we only focus on the organic fertiliser. Liming material (PFC 2) is composed of calcium or magnesium oxides, hydroxides, carbonates or silicates to correct soil acidity. Neutralising value, reactivity and grain size shall be determined on the basis of mass of a liming material. A soil improver (PFC 3) shall function to maintain, improve or protect properties and structure of the amended soil, as well as the biological activities within. The organic soil improver shall contain more than 20% dry matter and at least 7.5% C_{org} . The inhibitor (PFC 5) aims to improve nutrient release pattern of the product through delaying or stopping microbial or enzymatic activities. Biostimulant (PFC 6) cares the plant growth, while growing media (PFC 4) is to grow plants or mushrooms. Finally, fertilising product blend (PFC 7) composes of more than one fertilising product mentioned above.

The partners initially proposed four categories of fertilising products, namely, plant biostimulant (n. 8), organic fertiliser (n. 15), foliar fertiliser (n.1), soil improver/growing media (n. 1) and liming material (n. 1). Organic fertilisers shall provide nutrients to plants, so that the primary nutrients N, P, K are important parameters to evaluate BBF products (Table 5). 'Straight' indicates that fertiliser products contain only one declared nutrient, while 'Compound' refers to more declared nutrients.

Table 5 Nutrient and C_{org} requirements for organic fertiliser (PFC 1) according to the Regulation (EU) 2019/1009 (% by mass).

Nutrients	Organic fertiliser			
	Solid		Liquid	
	Straight	Compound	Straight	Compound
N	2.5	1	2	1
P ₂ O ₅	2	1	1	1
K ₂ O	2	1	2	1
Sum of nutrients		4		3
C _{org}		15		5

Based on fertilizing product Regulation (EU) 2019/1009, Liming materials (PFC 2) shall meet three parameters determined on the basis of the mass: minimum neutralizing value, minimum reactivity (10% hydrochloric acid test or 50% after 6 months incubation test) and minimum grain size. The neutralizing value can be expressed as CaO (minimum value: 15) or HO- (minimum value: 9). At least 70% of the grain size of the liming material shall smaller than 1mm, except for burnt limes, granulated liming material and chalk. As for the liming material 'UNI4' from WP3, the neutralising value (equivalent to CaO) equals to 56.18±0.54 (> 15), while (73.42±2.33) % of the liming material passed through a 1mm sieve. The reactivity of the liming material (>1mm) is 22.8%, while the portion <1mm has much higher reactivity value as 80.5%.

The organic carbon (C_{org}) contents in the BBF products ranged from 0.05% FW to 46.54% FW. Except for four liquid products with high moisture, the other seven liquid BBF products had more than 5% FW organic carbon. Apart from the solid liming material 'UNI4', most of the solid BBF products contained more than 15% FW C_{org}. According to regulation (EU) 2019/1009 fertilising products (Table 5), C_{org} in a solid organic fertiliser shall be at least 15% by mass, and 5% by mass in a liquid organic fertiliser. According to this, seven liquid BBF products and 12 solid products have the potential to be used as organic fertilisers based on C_{org} content only (Figure 1). Apart from liming material, the other two solid products, 'VER' with 7.67% C_{org} by mass and 'OA1' with 10.31% C_{org} by mass (Figure 1), are lower than the regulated minimal amount of C_{org} (15%). However, since the moisture content of these two product were determined as around 54% (Table 2), their C_{org} can reach 15% after further drying. The proposed soil improver 'VER' and 'UNI2' met this criterium with 7.67% FW and 40.09% FW C_{org}, respectively. The dry matter contents of 'VER' and 'UNI2' were 45.54% and 94.59%, respectively.

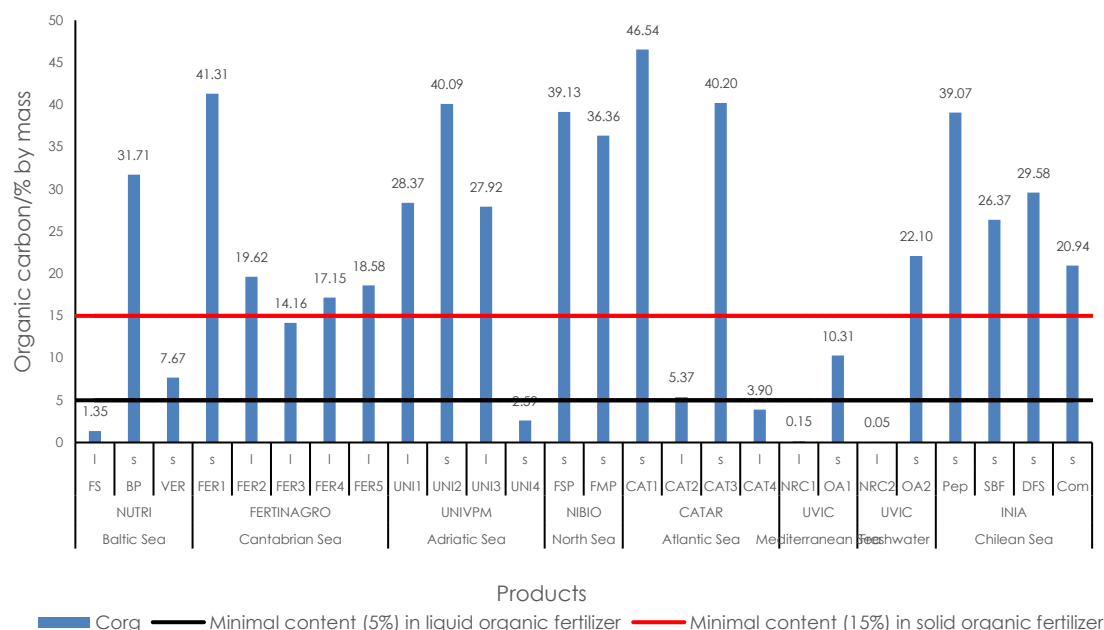


Figure 1 Organic carbon (C_{org}) content of BBF products and comparison to the regulated minimal contents of C_{org} in solid and liquid organic fertilisers, respectively.

The content of primary nutrients N, P and K varied remarkably in different BBF products. The TN content of these products had a big range, with the highest value 11.13% FW and extremely low content less than 0.01% FW (Table 3). Five liquid BBF products with highest moisture content had less than 2% FW TN (Figure 2). The other six dense liquid products contained 3.90 - 11.13% FW TN. For solid BBF products, 11 of them had more than 2.5% FW TN within, in which 'DFS' from Chile had highest TN content as 10.77% FW. Five products: liming material 'UNI4', 'FS', 'VER', 'NRC1' and 'NRC2' are not qualified to be used as compound fertilisers. While the products with less TN contents within, namely 'CAT1', 'CAT3', 'OA1' and 'SBF' can be considered as compound organic fertilisers with >1% FW TN. The ammonium contents of products ranged from 0.01 g/kg FW to 12.00 g/kg FW. Solid product 'FER1' had highest ammonium content. Two dense and viscous liquid products from UNIVPM were composed of > 10 g/kg of ammonium contents (Table 3). Most of the BBF products had < 0.002 g/kg nitrate and nitrite. Chilean 'SBF' contained highest nitrate and nitrite (0.37 g/kg FW).

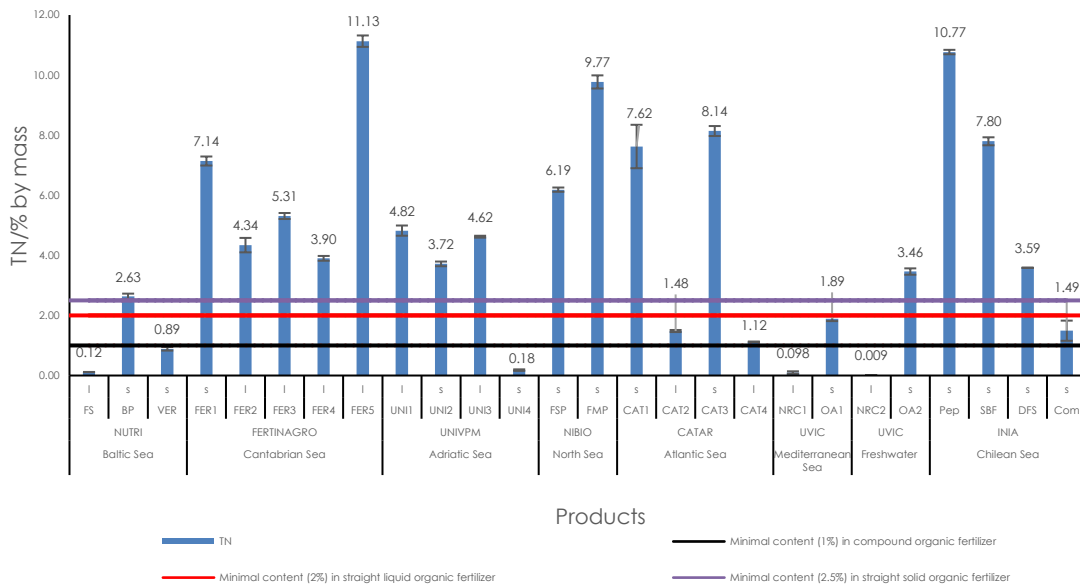


Figure 2 Total nitrogen (TN) contents of BBF products and comparison to the regulated minimal contents of TN in the organic fertilisers.

The oxidized forms of P and K limits (i.e., P₂O₅ and K₂O) given in the EU Regulation 2019/1009 were converted to elemental forms of P and K and further discussed accordingly. Considering the P contents of BBF products, 'OA1' from UVIC had the highest value, reaching 12.51% FW, while 'NRC1' and 'NRC2' from UVIC almost had no P (Table 3). In total, 12 BBF products had the potential to be used as straight P organic fertilisers (

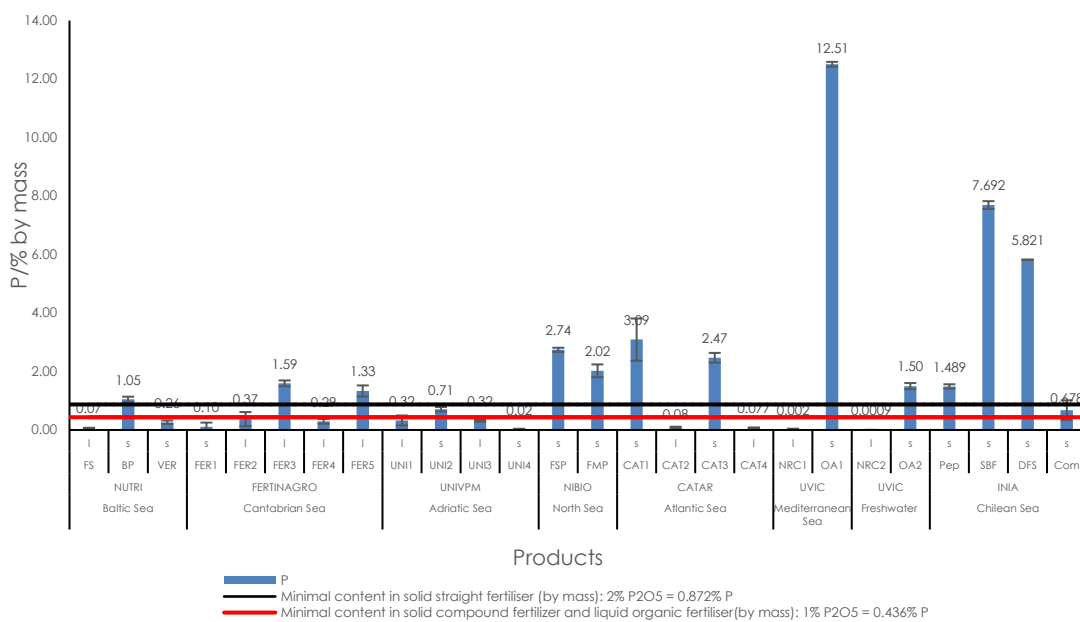


Figure 3). Except the liming material and the liquid products with very high content of water, the mobile P contents varied from 0.86 g/kg FW to 38.72 g/kg FW (Table 3). The mobile P contents consisted 15.04% to 100% of total P in different products. Products 'FER1' and 'UNI3' can be 100% mobile in the soil and for plants. Although 'OA1' had highest total P content, its mobile P content was only around 18.81 g/kg FW. The 'FMP' from NIBIO had 5.6% FW of K and was the only solid BBF product with such high K content (Figure 4).

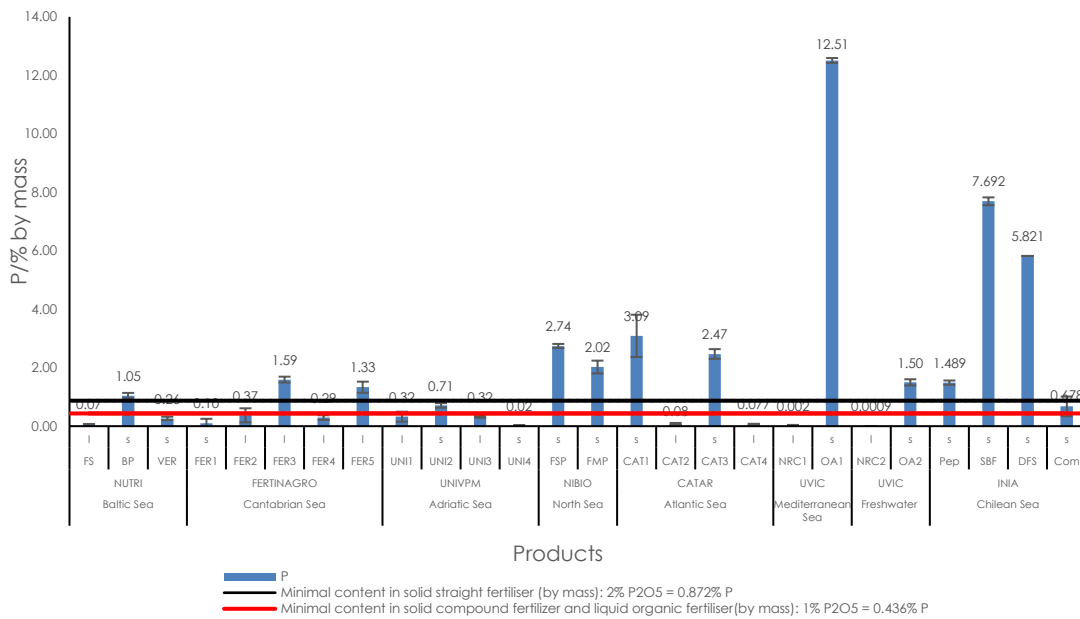


Figure 3 Phosphorus (P) content of BBF products and comparison to the regulated minimal contents of P₂O₅ (1% P₂O₅ = 0.436% P) in the organic fertilisers.

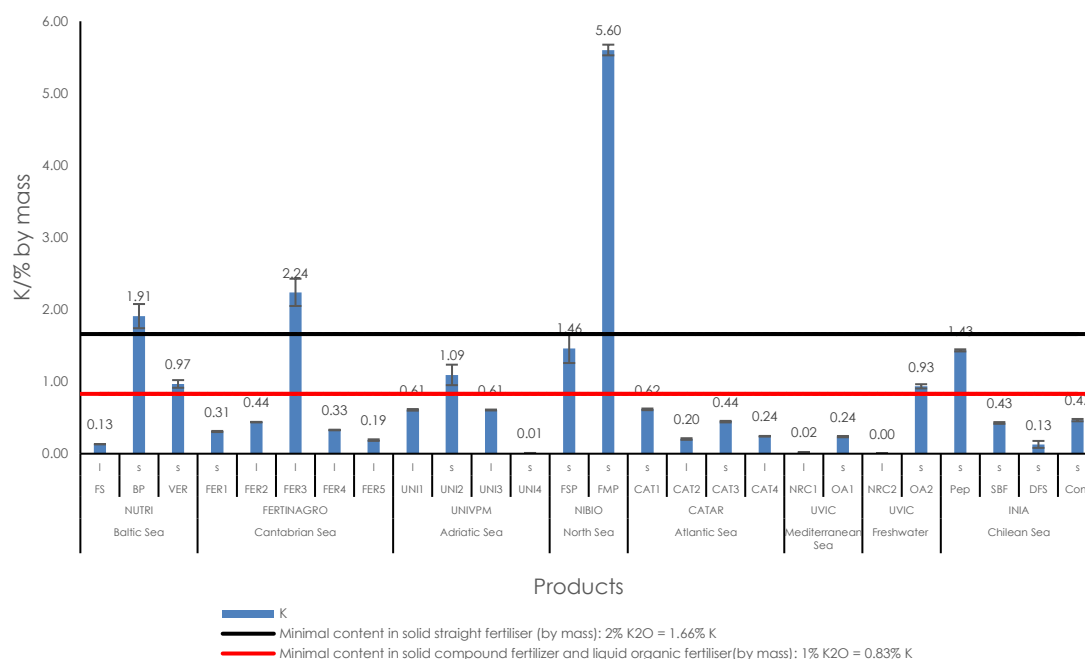


Figure 4 Potassium (K) content of BBF products and comparison to the regulated minimal contents of K₂O (1% K₂O = 0.83% K) in the organic fertilisers.

According to the EU regulation, fertilising products with lower content of single primary nutrient can be declared as compound fertilisers, with the sum of N, P₂O₅, K₂O contents exceeding 4% by mass for solid products and 3% for liquid ones. The sum contents of N, P₂O₅, K₂O were between 0.02% FW to 30.86% FW. Accordingly, eight BBF products ('FS', 'VER', 'UNI4', 'CAT2', 'CAT4', 'NRC1', 'NRC2', 'Com') were excluded from being qualified as organic fertilisers (Figure 5), while 'Com' can be used as growing medium/soil improver.

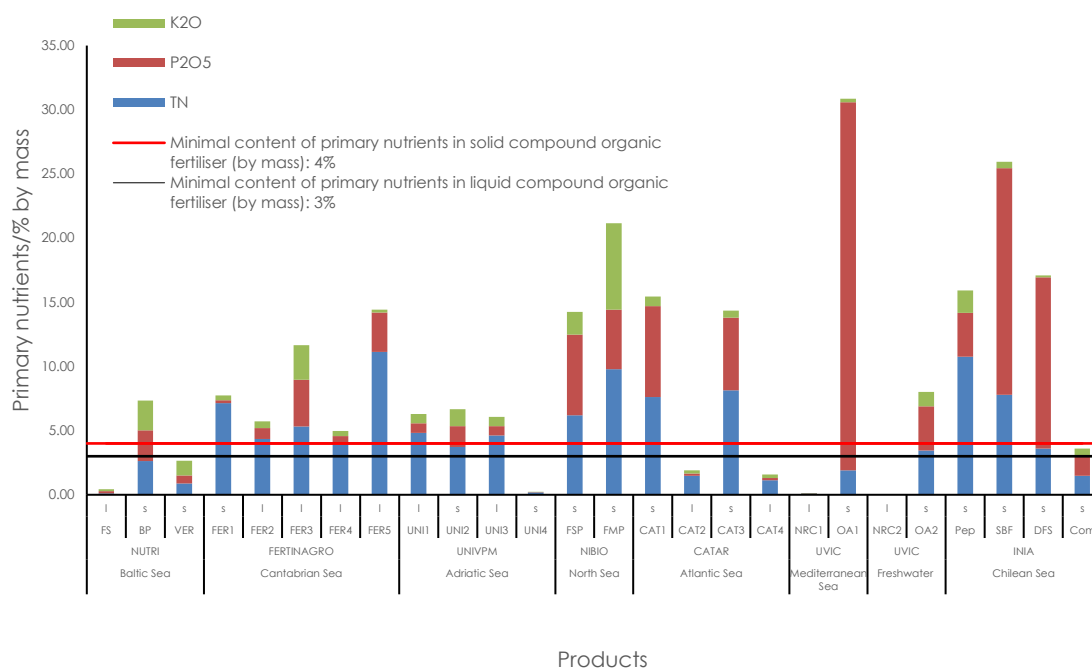


Figure 5 Primary nutrients NPK, expressed in TN, P₂O₅, K₂O forms and comparison to the regulated minimal contents of primary in compound organic fertilisers.

Besides the primary nutrients N, P and K, the BBF products had various contents of secondary nutrients, Ca, Mg, Na and S. The content of Ca ranged from 0.07 g/kg FW to 355.71 g/kg FW, Mg from 0.01 g/kg FW to 9.89 g/kg FW, Na from 0.21 g/kg FW to 28.03 g/kg FW, and S from 0.02 g/kg to 66.22 g/kg FW (Table 4).

Because of the marine source of most of the BBF products, iodine is an interesting element, which can be treated as a nutrient to the areas facing iodine scarcity. The 'OA1' from UVIC had very high content of iodine, reaching 114.31 mg/kg FW (Table 6). The iodine contents of other products varied between 0.03 mg/kg FW and 15.92 mg/kg FW. All solid products and 2 dense liquid BBF products from UNIVPM had iodine contents >1 mg/kg, which are higher than that of many fertilisers (Fuge and Johnson, 1986; Johnson, 2003).

Table 6 Iodine content of BBF products (expressed as mean ± standard deviation by fresh weight and dry weight).

Task	Area	Lead	Code	Form	I/(mg/kg FW)	I/(mg/kg DW)
3.1	Baltic Sea	NUTRI	FS	l	0.03 ± 0.005	1.36 ± 0.19
			BP	s	1.58 ± 0.07	1.74 ± 0.07
			VER	s	1.15 ± 0.04	2.52 ± 0.08
3.2	Cantabrian Sea	FERTINAGRO	FER1	s	0.59 ± 0.01	0.66 ± 0.01
			FER2	l	0.55 ± 0.02	1.54 ± 0.05

			FER3	l	0.38 ± 0.01	1.11 ± 0.04
			FER4	l	0.21 ± 0.01	0.57 ± 0.03
			FER5	l	0.14 ± 0.02	0.31 ± 0.03
3.3	Adriatic Sea	UNIVPM	UNI1	l	3.72 ± 0.23	8.82 ± 0.56
			UNI2	s	5.11 ± 0.20	5.40 ± 0.21
			UNI3	l	3.65 ± 0.05	8.62 ± 0.11
			UNI4	s	1.50 ± 0.10	1.50 ± 0.10
4.1	North Sea	NIBIO	FSP	s	4.20 ± 0.34	4.45 ± 0.36
			FMP	s	2.33 ± 1.37	2.46 ± 1.45
4.2	Atlantic Sea	CATAR	CAT1	s	3.66 ± 0.17	3.74 ± 0.17
			CAT2	l	0.39 ± 0.01	3.53 ± 0.07
			CAT3	s	n.m*	n.m
			CAT4	l	n.m	n.m
4.3	Mediterranean Sea	UVIC	NRC1	l	2.69 ± 0.11	1543.62 ± 60.71
			OA1	s	114.31 ± 8.19	248.33 ± 17.79
4.4	Freshwater	UVIC	NRC2	l	0.04 ± 0.00	1.12 ± 0.10
			OA2	s	2.82 ± 0.18	5.76 ± 0.37
Chile	Chilean Sea	INIA	DFS	s	1.35 ± 0.02	1.48 ± 0.02
			Com	s	5.49 ± 0.22	6.00 ± 0.24
			Pep	s	15.92 ± 0.36	16.29 ± 0.36
			SBF	s	10.22 ± 3.75	11.66 ± 4.28

*n.m: not measured (due to later production of the products)

Free amino acids are primarily utilized for the synthesis of seed-storage proteins, but also serve as precursors for the biosynthesis of secondary metabolites and as a source of energy. The free amino acid content in the (potential) plant biostimulant products of FERTINAGRO were found as 16.1%, 21.4%, 9.8%, 7.5% and 0.8% for FER1, FER2, FER3, FER4 and FER5, respectively. While the free amino acids in the (potential) plant biostimulants of CATAR, namely CAT2 and CAT4, were 0.6% and 0.8%, respectively; and hydrolysate produced by UNIVPM (UNI1) contained 3.5% free amino acids. Although CAT2 and CAT4 met the safety requirements of the Regulation (EU) 2019/1009, their low free amino acid content limits their use as biostimulants since these products exhibited only amino acids and peptides and need a concentration step.

3.3 Safety assessment of BBF products

Fishery waste-derived fertilising products carry the risks of contamination with pathogens, heavy metals, and organic pollutants which may render the BBF not qualified as fertilising product. The application of unqualified fishery waste derived fertiliser with excess pathogens may pose a risk of pathogenic contamination to surface water and groundwater. The transferring of pathogens in the food chain can pose serious risks to human health (Seleiman et al., 2020). It is necessary to monitor pathogens

in the fishery waste-derived fertilisers before applying to the field. According to Regulation (EU) 2019/1009, pathogen control of fertilising products focuses on *Salmonella spp.* with the maximum value of the number of bacteria being absence in 25 g or 25 ml of fertilising products, *Escherichia coli* or *Enterococcaceae* being 1000 in 1 g or 1 ml, except microbial plant biostimulants. Other contaminants can also influence the quality of derived fertilising products. Except for pathogens, there is little variation between the limit values of seven PFCs, such as heavy metals Cd, Pb and Hg, as well as the maximal concentration limits of Cu and Zn (Table 7). Instead of total As and Cr, more toxic forms, inorganic As (iAs) and hexavalent Cr (Cr(VI)) were taken into account when assessing the safety of fertilising products.

Table 7 Limit values of heavy metals, Cu and Zn in fertilising products discussed in this report based on Regulation (EU) 2019/1009 (Unit: mg/kg DW).

		Fertiliser	Liming material	Soil improver		Growing medium	Plant biostimulant
		Organic		Organic	Inorganic		
Heavy metals	Cd	1.5	2	2	1.5	1.5	1.5
	Cr (VI)	2	2	2	2	2	2
	Hg	1	1	1	1	1	1
	Ni	50	90	50	100	50	50
	Pb	120	120	120	120	120	120
	iAs	40	40	40	40	40	40
	Biuret	not present					
Cu&Zn	Cu	300	300	300	300	200	600
	Zn	800	800	800	800	500	1500

Aluminum (Al) contents in most of the BBF products were less than 5 mg/kg DW, and iron (Fe) content ranged from 0.01 to 19.16 mg/kg DW (Table 8). Except 'NRC1', Cu and Ni of the BBF products were lower than 200 mg/kg DW and 50 mg/kg DW and within the limit values (Table 7). Apart from products 'OA1', 'OA2' from UVIC and 'Pep' from Chile, Zn contents did not exceed the limit value in the BBFs. The Pb contents of all products met the limits of all categories of fertilising products. The product 'DFS' from INIA, Chile, was the only product exceeded the Cd limit (Table 8). The Co contents were lower than 7 mg/kg DW. The total Cr content ranged from <0.11 mg/kg DW to 41.7 mg/kg DW. The As and Hg contents were all within the limits of the regulation, 40 mg/kg DW (for iAs) and 1 mg/kg DW, respectively (Figure 6, Figure 7 and Table 8).

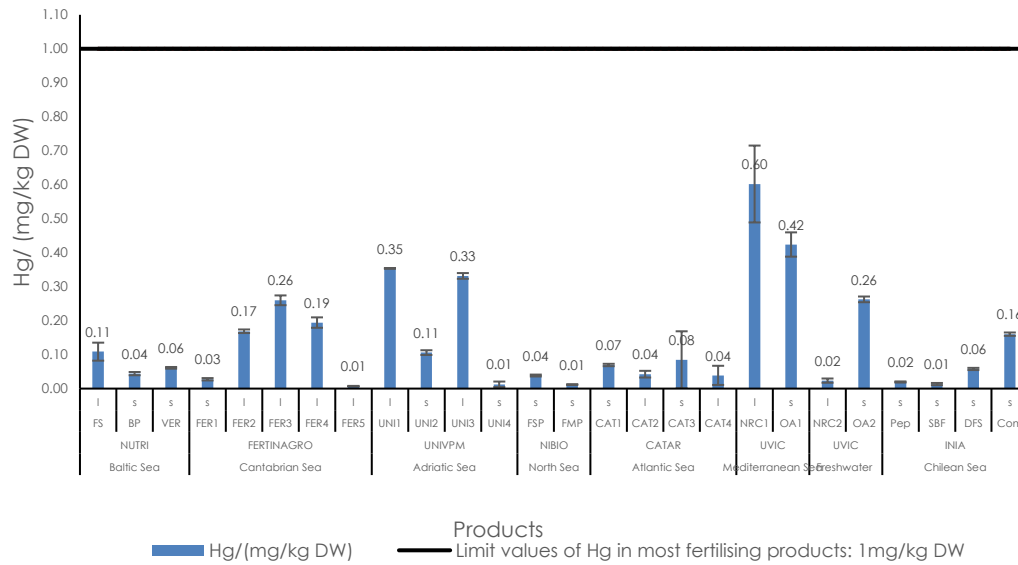


Figure 6 Hg contents of BBF products and comparison to the regulated limit value of Hg= 1mg/kg DW in most fertilising products.

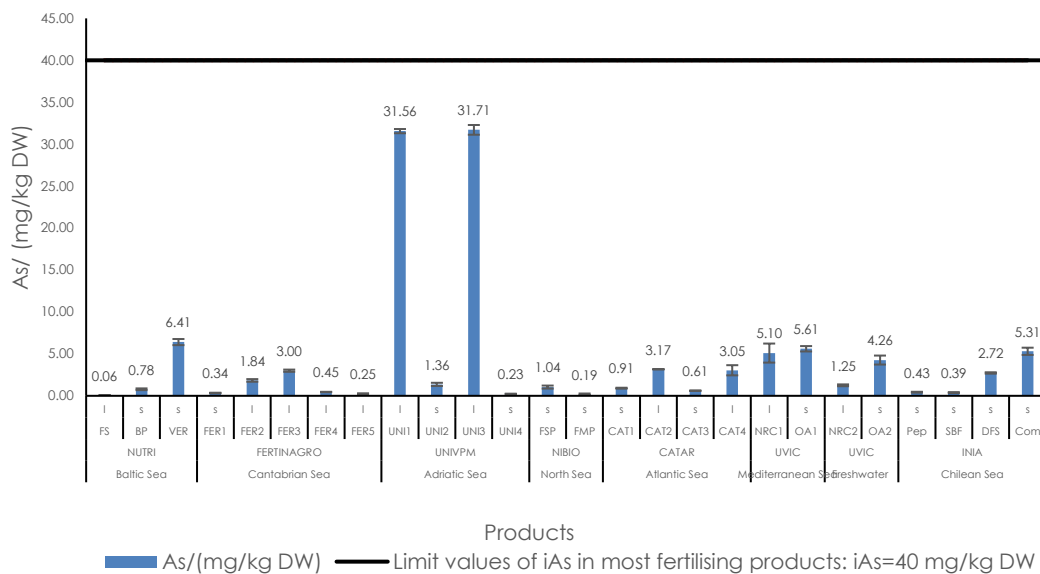


Figure 7 As contents of BBF products and comparison to the regulated limit value of iAs= 40 mg/kg DW in most fertilising products.

Excessively high biuret concentrations can damage seedlings (Mikkelsen, 1990), so it should not be detected in organic fertilisers. The biuret content of all proposed organic fertilisers were below the detection limit (0.01%) except for one BBF, 'FMP' from NIBIO, which was just slightly above the detection limit (0.0155%) and is still acceptable. The BBF product 'VER' from the Baltic Sea Pilot was already qualified as a soil improver

based on its C_{org} and nutrients content before the biuret analysis, so that 'VER' was not included in the biuret determination.

Based on the total Cr concentrations (Table 8), 16 BBF samples were selected and sent for further Cr(VI) determination. By the time of the submission of the Report, the results of only 6 samples (FER2, FER3, UNI1, UNI3, CAT4, NRC1) were received and all were found below the limit (2 mg/kg DW) given in the Regulation (EU) 2019/1009. More specifically, all 4 samples were detected below 0.1 mg/kg DW except for CAT4 which was below 0.2 mg/kg DW and NR1 below 0.3 mg/kg DW.

The pathogen analysis showed that 'VER' from NUTRI and 'OA2' from UVIC exceeded the maximum value of the number of *E. coli*, while no pathogens were detected in the others (Table 9). OA2 could not meet the requirement to be used as organic fertiliser, while VER met all the requirements for growing medium/soil improver except for pathogen content and therefore needs to be pasteurized before being applied to soil.

Nutrient recovery and recycling through the utilization of bio-based fertilising products derived from fishery waste and by-products fit perfectly well to the targets of Farm to Fork strategy which aims to reduce nutrient losses to the environment from both organic and mineral fertilisers by at least 50% by 2030. BBFs derived from fishery waste and/or by-products have not been yet included as a component material category in the EU 2019/1009 Fertilising Products Regulation. Where regulations control the use of fertilising products derived from fishery waste, exemptions could be made to allow easier valorization and open the way of single market for these products.

As already reported in the Deliverable D2.1, the EU legislation, Directives and Regulations, apply to all EU countries via their transposition to national laws. The EU member states follow the EU regulations and directives as a common background and there is no significant differences at the national level. Although Norway is not part of the EU, it is a member of the EEA (European Economic Area) and therefore it also follows many of the regulations and directives coming from the EC. Chile is eventually a case apart but provides a good example of legislation and regulations in force out of the European region. Within this Report, the BBF products from Chile were assessed based on the EU Regulation 1009/2019 considering their possible potential uptake and future replicability in Europe.

Table 8 Metal contents of BBF products (expressed as mean \pm standard deviation, dry weight).

Task	Area	Lead	Code	Form	Al (g/kg)	Fe (g/kg)	Mn(mg/kg)	Cu (mg/kg)	Zn (mg/kg)
3.1	Baltic Sea	NUTRI	FS	l	0.10 \pm 0.00	0.89 \pm 0.02	45.51 \pm 0.93	< 0.14	174.93 \pm 3.15
			BP	s	3.61 \pm 0.48	4.50 \pm 1.55	561.34 \pm 81.62	12.35 \pm 9.22	211.4 \pm 7.00
			VER	s	19.08 \pm 0.80	19.16 \pm 0.93	656.82 \pm 69.33	120.88 \pm 0.67	507.69 \pm 42.00
3.2	Cantabrian Sea	FERTINAGRO	FER1	s	0.11 \pm 0.01	0.11 \pm 0.00	40.47 \pm 0.41	12.56 \pm 0.32	61.40 \pm 0.66
			FER2	l	0.14 \pm 0.02	0.12 \pm 0.00	4.06 \pm 0.14	135.45 \pm 4.04	569.26 \pm 12.65
			FER3	l	0.13 \pm 0.00	0.12 \pm 0.02	13.61 \pm 2.29	93.76 \pm 15.52	577.61 \pm 95.11
			FER4	l	0.17 \pm 0.02	0.10 \pm 0.01	25.74 \pm 0.46	71.00 \pm 1.48	436.57 \pm 4.37
			FER5	l	0.11 \pm 0.01	0.02 \pm 0.00	30.42 \pm 2.17	< 2.25	10.42 \pm 0.84
3.3	Adriatic Sea	UNIVPM	UNI1	l	0.22 \pm 0.01	0.42 \pm 0.00	< 0.32	148.5 \pm 6.89	640.80 \pm 7.03
			UNI2	s	2.57 \pm 0.86	2.57 \pm 0.80	63.77 \pm 18.08	52.39 \pm 13.14	90.94 \pm 18.21
			UNI3	l	0.23 \pm 0.03	0.41 \pm 0.00	< 0.32	159.51 \pm 10.55	649.76 \pm 9.47
			UNI4	s	< 0.01	0.08 \pm 0.01	< 0.27	< 3.76	< 0.62
4.1	North Sea	NIBIO	FSP	s	0.77 \pm 0.11	1.14 \pm 0.20	115.02 \pm 21.67	< 1.12	400.61 \pm 71.01
			FMP	s	0.25 \pm 0.02	1.24 \pm 0.05	18.05 \pm 6.8	< 1.12	164.89 \pm 29.38
4.2	Atlantic Sea	CATAR	CAT1	s	0.11 \pm 0.02	0.04 \pm 0.00	< 0.27	< 3.82	67.62 \pm 3.34
			CAT2	l	0.30 \pm 0.07	0.01 \pm 0.00	0.36 \pm 0.08	2.99 \pm 0.43	12.49 \pm 0.75
			CAT3	s	0.29 \pm 0.04	0.32 \pm 0.04	18.99 \pm 2.89	7.65 \pm 0.86	85.30 \pm 3.20
			CAT4	l	0.04 \pm 0.01	0.03 \pm 0.01	1.46 \pm 0.33	4.33 \pm 1.37	6.74 \pm 1.26
4.3	Mediterranean Sea	UVIC	NRC1	l	0.22 \pm 0.03	0.43 \pm 0.01	< 0.50	354.52 \pm 15.14	213.14 \pm 21.66
			OA1	s	4.36 \pm 0.87	7.71 \pm 0.71	627.29 \pm 11.86	6.39 \pm 2.41	2435.63 \pm 385.07
4.4	Freshwater	UVIC	NRC2	l	0.03 \pm 0.00	0.02 \pm 0.00	< 0.02	1.12 \pm 0.31	8.03 \pm 1.45
			OA2	s	45.74 \pm 4.61	7.75 \pm 1.89	263.9 \pm 31.09	< 2.16	2341.64 \pm 564.08
Chile	Chilean Sea	INIA	Pep	s	0.11 \pm 0.03	0.51 \pm 0.02	10.31 \pm 0.3	15.69 \pm 0.36	187.73 \pm 2.33
			SBF	s	0.09 \pm 0.02	0.60 \pm 0.27	50.38 \pm 2.42	14.25 \pm 0.49	332.52 \pm 1.79
			DFS	s	2.15 \pm 0.07	2.17 \pm 0.26	437.20 \pm 3.4	27.72 \pm 1.84	1125.46 \pm 24.77
			Com	s	4.64 \pm 0.02	7.96 \pm 1.51	284.19 \pm 2.02	57.28 \pm 0.5	237.25 \pm 0.54

Table 8 (continued) Metal contents of BBF products (expressed as mean \pm standard deviation, dry weight).

Task	Area	Lead	Code	Form	Cd (mg/kg)	Co (mg/kg)	Cr (mg/kg)	Cr(VI) (mg/kg)	Ni (mg/kg)	Pb (mg/kg)
3.1	Baltic Sea	NUTRI	FS	l	< 0.23	< 0.35	< 0.15	-	< 5.34	< 4.02
			BP	s	< 0.77	< 3.01	18.63 \pm 7.34		< 23.23	< 34.15
			VER	s	< 1.54	< 5.98	22.82 \pm 2.38		< 46.23	< 67.98
3.2	Cantabrian Sea	FERTINAGRO	FER1	s	< 0.39	< 0.88	3.21 \pm 0.27		4.93 \pm 0.14	< 16.04
			FER2	l	< 0.49	< 1.10	4.28 \pm 1.12	<0.10	4.93 \pm 1.14	< 20.13
			FER3	l	1.16 \pm 0.13	< 1.14	2.82 \pm 0.46	<0.10	4.22 \pm 0.39	< 20.76
			FER4	l	< 0.47	< 1.07	1.30 \pm 0.27	-	1.95 \pm 0.16	< 19.52
			FER5	l	< 0.37	< 0.85	0.82 \pm 0.09	-	0.76 \pm 0.29	< 15.43
3.3	Adriatic Sea	UNIVPM	UNI1	l	< 0.98	< 2.96	< 2.52	<0.10	< 1.23	< 3.16
			UNI2	s	< 0.88	< 2.64	< 1.12	-	< 1.09	< 2.81
			UNI3	l	< 0.98	< 2.96	< 2.52	<0.10	< 1.23	10.95 \pm 1.96
			UNI4	s	< 0.83	< 2.50	< 1.06	-	< 1.04	< 2.67
4.1	North Sea	NIBIO	FSP	s	< 0.74	< 2.89	< 1.26	-	< 22.30	< 32.80
			FMP	s	< 0.74	< 2.88	< 1.26	-	< 22.28	< 32.76
4.2	Atlantic Sea	CATAR	CAT1	s	< 0.85	< 2.54	2.02 \pm 0.88	-	< 1.06	< 2.71
			CAT2	l	< 0.31	< 0.70	0.66 \pm 0.20	-	3.2 \pm 0.42	< 12.85
			CAT3	s	< 0.06	< 1.85	9.03 \pm 1.45		14.68 \pm 2.48	< 29.97
			CAT4	l	< 0.14	< 4.26	2.72 \pm	<0.20	23.82 \pm 30.35	< 68.77

D6.1

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							0.77			
4.3	Mediterranean Sea	UVIC	NRC1	l	< 1.35	< 5.21	< 2.27	<0.30	< 78.46	< 59.14
			OA1	s	< 1.52	< 5.92	11.86 ± 4.48		< 45.74	< 67.26
4.4	Freshwater	UVIC	NRC2	l	< 0.07	< 0.25	< 0.11	-	< 3.82	< 2.88
			OA2	s	< 1.43	< 5.57	< 2.43	-	< 43.02	< 63.26
Chile	Chilean Sea	INIA	Pep	s	< 0.63	< 0.88	1.48 ± 0.11	-	< 0.56	< 26.94
			SBF	s	< 0.63	< 0.88	4.51 ± 2.15		< 0.56	< 26.77
			DFS	s	3.26 ± 0.05	6.67 ± 1.00	15.39 ± 10.81		< 0.52	< 25.03
			Com	s	0.48 ± 0.01	4.79 ± 0.09	41.71 ± 7.59		6.44 ± 0.35	< 27.92

Table 9 Pathogens in the BBF products.

Task	Area	Lead	Code	BBF product	Form	Salmonella spp.	Faecal coliforms	E. coli
						Detected/25g	UFC/g	UFC/g
3.1	Baltic Sea	NUTRI	FS	1) Foliar fertiliser	l	n. d.	<10	<10
			BP	2) Bokashi pellet	s	n. d.	<10	<10
			VER	3) Vermicompost and/or substrate	s	n. d.	<10	90
3.2	Cantabrian Sea	FERTINAGRO	FER1	1) Amino acids, organic matter and humic extract	s	n. d.	<10	<10
			FER2	2) Foliar fertiliser with N and amino acids	l	n. d.	<10	<10
			FER3	3) NPK solution with amino acids	l	n. d.	<10	<10
			FER4	4) Foliar fertiliser with amino acid, humic extract, organic matter	l	n. d.	<10	<10
			FER5	5) Fertiliser with humic acids	l	n. d.	<10	<10
3.3	Adriatic Sea	UNIVPM	UNI1	1) Hydrolysates	l	n. d.	<10	<10
			UNI2	2) Biochar-compost composite	s	n. d.	<10	<10
			UNI3	3) Chitin-rich fertiliser	l	n. d.	<10	<10
			UNI4	4) CaCO ₃	s	n. d.	<10	<10
4.1	North Sea	NIBIO	FSP	1) Fish sludge pelleted fertiliser	s	n. d.	<10	<10
			FMP	2) Fish mix pelleted fertiliser	s	n. d.	<10	<10
4.2	Atlantic Sea	CATAR	CAT1	1) Protein fraction	s	n. d.	<10	<10
			CAT2	2) Amino acids and peptides	l	n. d.	<10	<10
			CAT3	3) Protein fraction_upgraded	s	n. d.	<10	<10
			CAT4	4) Amino acids and peptides_upgraded	l	n. d.	<10	<10
4.3	Mediterranean Sea	UVIC	NRC1	1) Nutrient-rich concentrate	l	n. d.	<10	<10
			OA1	2) Organic amendment	s			
4.4	Freshwater	UVIC	NRC2	1) Nutrient-rich concentrate (BBF1)	l	n. d.	<10	<10
			OA2	2) Organic amendment (BBF2)	s	n. d.	<10	170

Comments: n.d. indicates to 'not detected'.

4 Conclusion

Based on the results, 12 BBF products can be categorized as organic fertilisers (Table 10), while two of them (OA1 and OA2 from the Mediterranean Sea and Freshwater Pilots, respectively) require additional processing due to below-mentioned reasons in Table 10. There are seven potential (non-microbial) plant biostimulants with relevant features (e.g., free amino acids, humic acids), and their biostimulating effects need to be further tested based on the criteria given in the Regulation (EU) 2019/1009. The liming material and growing medium/soil organic improvers (one with pasteurisation condition) meet the EU requirements. A total of 8 products were selected to be further analysed for the N dynamics under controlled condition in Task 6.2 through soil incubation tests and for gaseous emissions in Task 6.4 (Table 10). Further investigation of the impacts on soil and plants are investigated via pot/field experiments under WP5 and WP6.

Table 10 Recommended products function categories and selected products for soil incubation (SI) and gaseous emissions (GE) tests.

Lead	BBF product	Code	Form	Proposed category	Recommended category	SI & GE
NUTRI	1) Foliar fertiliser	FS	l	Foliar Fertiliser	Plant biostimulant	
	2) Bokashi pellet	BP	s	Organic fertiliser	Organic fertiliser	x
	3) Vermicompost and/or substrate	VER	s	Organic fertiliser	Growing media/soil improver*	
FERTINAGRO	1) Amino acids, organic matter and humic extract	FER1	s	Plant biostimulant	Plant biostimulant	
	2) Foliar fertiliser with N and amino acids	FER2	l	Plant biostimulant	Plant biostimulant	
	3) NPK solution with amino acids	FER3	l	Plant biostimulant	Organic fertiliser (with potential biostimulating effect)	x
	4) Foliar fertiliser with amino acid, humic extract, organic matter	FER4	l	Plant biostimulant	Plant biostimulant	
	5) Fertiliser with humic acids	FER5	l	Plant biostimulant	Plant biostimulant	
UNIVPM	1) Hydrolysates	UNI1	l	Plant biostimulant	Organic fertiliser (with potential biostimulating effect)	x
	2) Biochar-compost composite	UNI2	s	Growing media/soil improver	Growing media/soil improver	
	3) Chitin-rich fertiliser	UNI3	l	Organic fertiliser	Organic fertiliser	x
	4) CaCO ₃	UNI4	s	Liming material	Liming material	
NIBIO	1) Fish sludge pelleted fertiliser	FSP	s	Organic fertiliser	Organic fertiliser	x
	2) Fish mix pelleted fertiliser	FMP	s	Organic fertiliser	Organic fertiliser	x
CATAR	1) Protein fraction	CAT1	s	Organic fertiliser	Organic fertiliser	x
	2) Amino acids and peptides	CAT2	l	Plant biostimulant	Plant biostimulant***	
	3) Protein fraction_upgraded	CAT3	s	Organic fertiliser	Organic fertiliser	
	4) Amino acids and peptides_upgraded	CAT4	l	Plant biostimulant	Plant biostimulant***	
UVIC	1) Nutrient-rich concentrate	NRC1	l	Organic fertiliser	<i>Not qualified</i>	
	2) Organic amendment	OA1	s	Organic fertiliser	Organic fertiliser***	x
UVIC (freshwater)	1) Nutrient-rich concentrate	NRC2	l	Organic fertiliser	<i>Not qualified</i>	
	2) Organic amendment	OA2	s	Organic fertiliser	Organic fertiliser****	
INIA	1) Peptone	Pep	s	Organic fertiliser	Organic fertiliser	
	2) Salmon bones flour	SBF	s	Organic fertiliser	Organic fertiliser	
	3) Dried fish sludge	DFS	s	Organic fertiliser	<i>Not qualified</i>	
	4) Compost	Com	s	Organic fertiliser	Growing media/soil improver	

Comments: *High *E. coli* content, **Due to low free amino acids content further concentration needed, ***Pretreatment (further drying) needed to adjust C_{org}, **** High *E. coli* and Zn content.

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