Session: Nutrient recovery from waste streams for healthy soils

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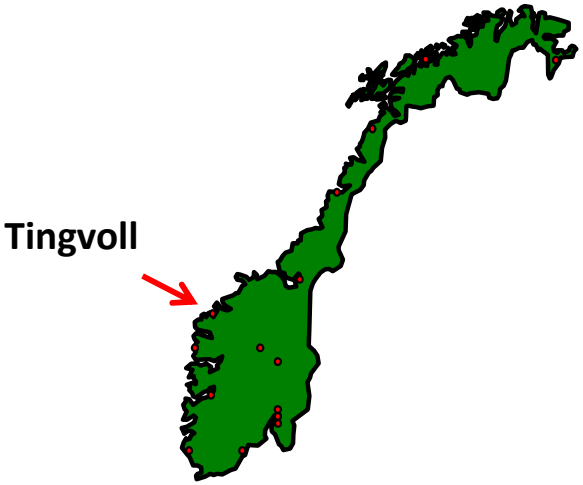
Nutrients from residual materials applied as fertilisers: possibilities, challenges and potential effects on soil biology

Anne-Kristin Løes, senior researcher, NORSØK

NORSØK: a hub for research and development in agronomy since 1986, located in Tingvoll, NW Norway



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Tingvoll farm - organically managed dairy production + experimental farm

22 dairy cows in loose housing

Biogas plant for cow manure since 2011, now converting to thermophilic process

Field experiments with residual materials as fertilisers (bio-based fertilisers, BBF)

Exhibition centre & cafe

45 people working with agriculture and environment

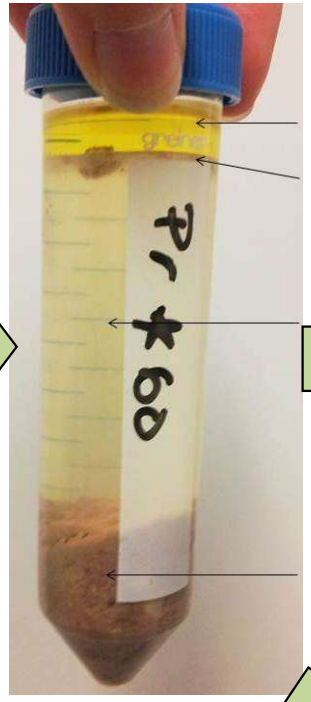
Starting point for BBF “CYCLE” project 2013-16: Complete utilization of chicken bones

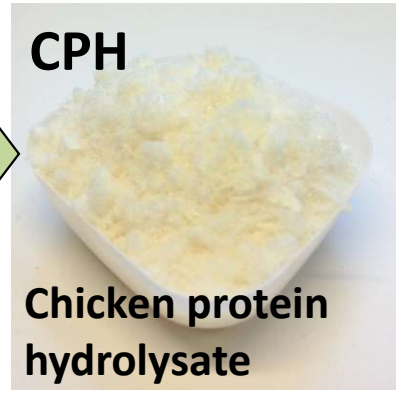
Raw material

- 17 % lipids
- 16 % proteins
- 5 % ash
- 63 % moisture

Raw material and **water**(1:1)
0.1 % enzyme (dry weight enzyme/wet weight raw material)

50 °C, 120 min

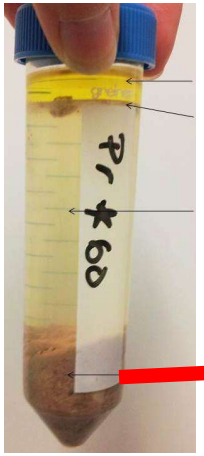


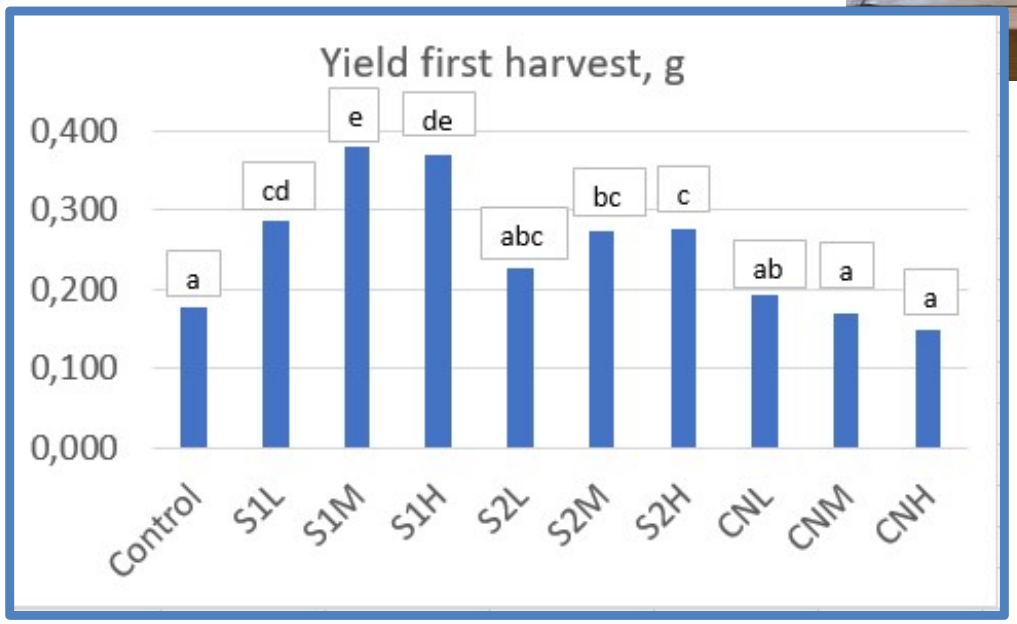


The Research Council of Norway

SINTEF OCEAN

Spin-off project 2017 on laying hens: Very rapid growth effect of sediments





Mean yields of ryegrass, g DM/pot (n= 5/treatment), plants cut at 4 cm

S1= Sediment 1 finely grinded

S2= Sediment 2 less finely grinded

CN= $CaNO_3$

L = low, M= medium, H= high N

as 200, 400, 600 kg N/ha

Seeds germinated on March 14, 2017;
1st harvest March 31, 2017

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Projects on marine-derived bio-based fertilisers (2018-2022): RESTOR and Organic-PLUS

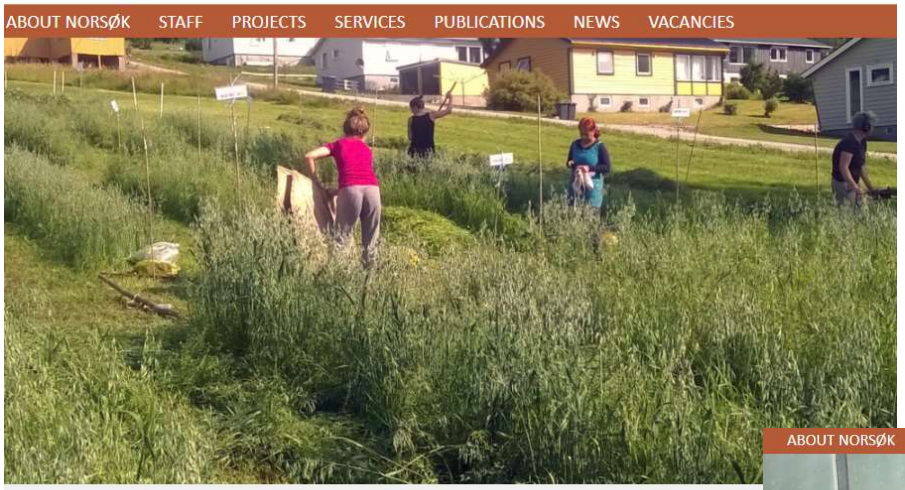
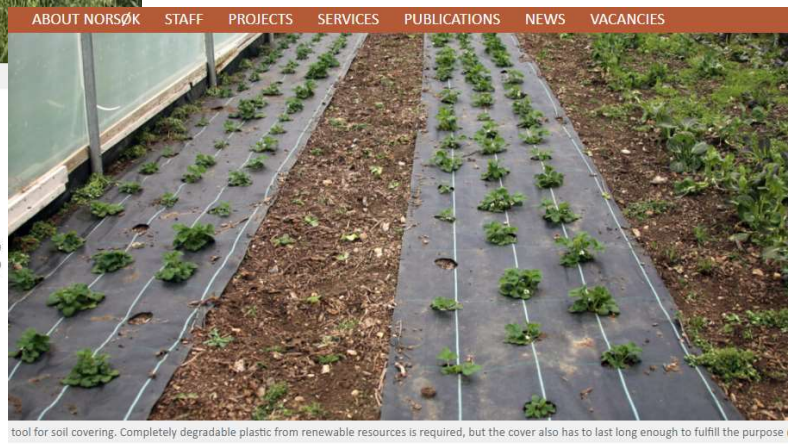


Foto Akl (Photo: Anne-Kristin Løes)

Residual materials from marine industries as fertilizers in organic agriculture (RESTOR)



tool for soil covering. Completely degradable plastic from renewable resources is required, but the cover also has to last long enough to fulfill the purpose

Pathways to phase-out contentious inputs from organic agriculture in Europe (Organic-PLUS)

- residues from captured fish

- residues from harvested seaweed (brown algae)

- permitted for use in certified organic growing

Møre og Romsdal county municipality

ORGANIC PLUS

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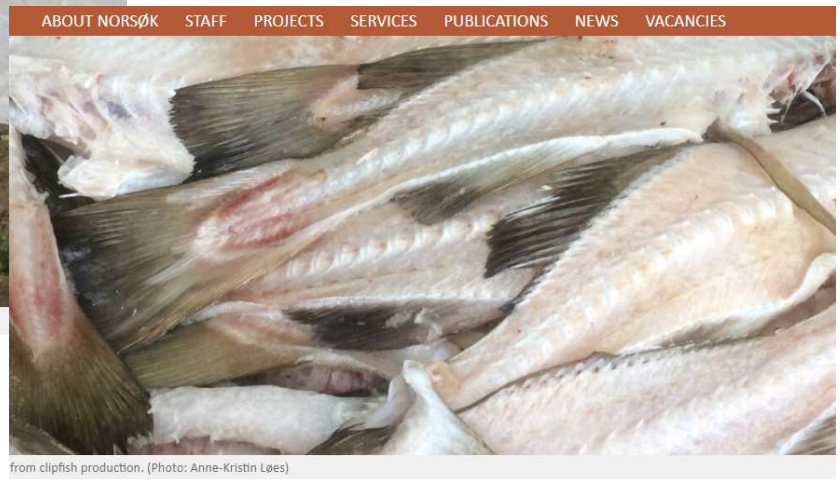
More specific research questions (2021-24): increased soil C from in seaweed – FIMO; composting to stabilise marine residues- MARIGREEN

n Sunndal, May 2019. (Photo: Anne-Kristin Løes)



from clipfish production. (Photo: Anne-Kristin Løes)

Seaweed fibre for increased soil organic matter - FIMO

Sustainable utilization of MARine resources to foster GREEN plant production in Europe - MARIGREEN

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Blue BIO COFUND — Coordinated R&D funding scheme to strengthen Europe's position in the blue bioeconomy

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Norway has a long coastline

Fish capture: 2.5mill tons live weight/year (white fish, herring ++)

Fish aquaculture: 1.5 mill tons/year (mainly salmon)

Seaweed harvest: and aquaculture:

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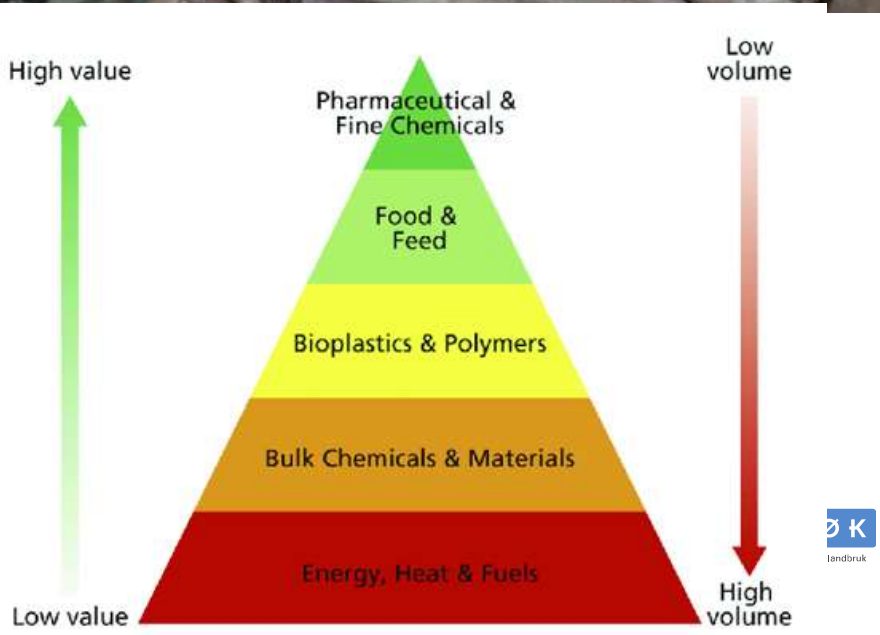
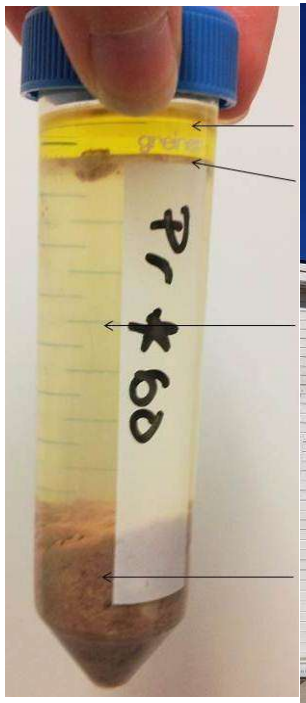
Significant volumes of organic material from captured fish and seaweed industry are poorly utilised

…. but product development still mostly aims at pharmacy, food and pet food

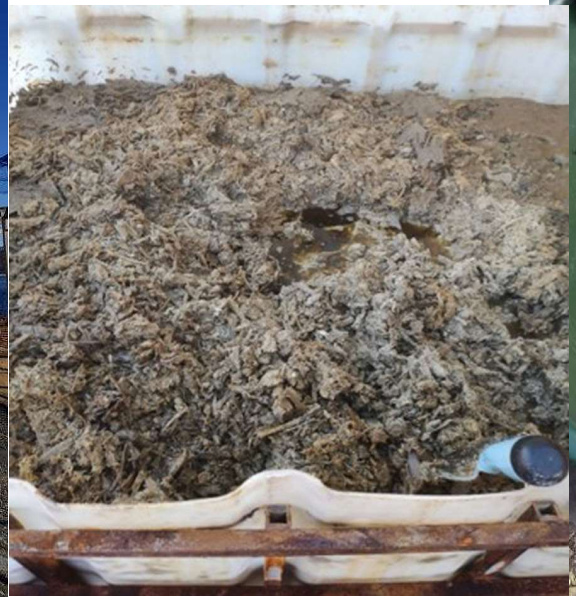


Fish residues (heads, backbones, viscera, skin…) need processing and preservation - acidification



Lab scale

Industry scale,
tank for hydrolysis of grinded fish residues, conserved by formic acid, pH < 4



Sediments containing mostly fish bones, ca. 50% dry matter,
currently wasted

Air-dried and sieved sediments
for field application

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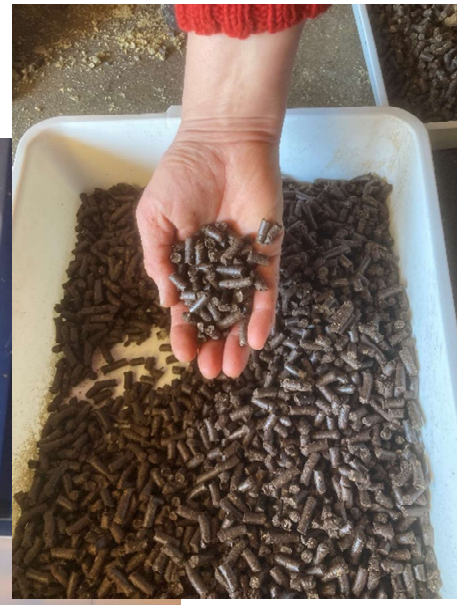
Fish residues need processing and preservation – combined drying, grinding, sieving – and pelletizing



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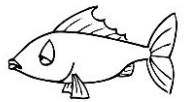
Fish residues = a rich source of P, Ca, N – but little K, Mg, S

Type of material	Acidified	Dried
pH	4.9	5.8
N % of DM	4.1	8.5
P % of DM	9.3	7.4
Ca % of DM	16	14.5
K % of DM	0.1	0.9
Mg % of DM	0.1	0.4
S % of DM	0.2	0.6



Crop plants demand N, P, K, Ca, Mg, S and a range of micro-nutrients

The Norwegian Food Safety Authority specifies that *fish* and *formic acid* are permitted inputs in regulations for organic production.
Fish must be ABP category 3, hence, dead fish from aquaculture (silage, cat.2) is not permitted

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Seaweed (brown algae) contains significant K, S and Mg

Rockweed (Ascophyllum nodosum) harvested, dried, ground and extracted for liquid fertiliser by Algea AS, Kristiansund, Norway

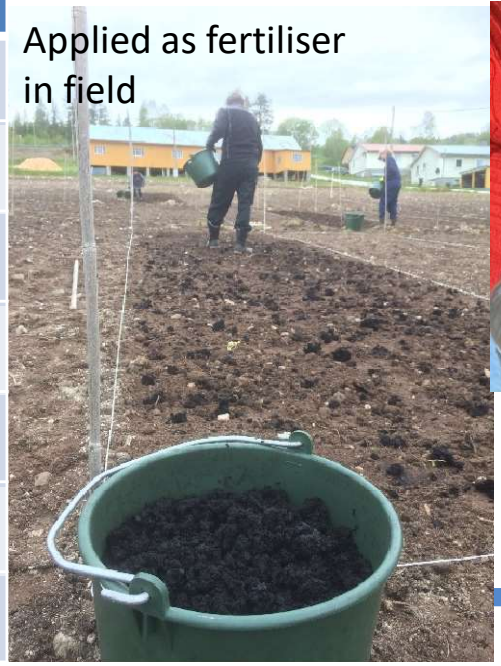
Residual material = «algae fibre»;
ca. 15 tons/week, currently incinerated

Product for sale:
AlgaFert Base, pH 5

Liquid fertilisers are permitted but not fibre residues, due to extraction with HNO_3

pH	9.6
DM, %	30
N % of DM	1.5
P % of DM	0.3
Ca % of DM	6.8
K % of DM	13
Mg % of DM	2.5
S % of DM	1.5

Applied as fertiliser in field



An excellent dough for making pellets of fishbone meal

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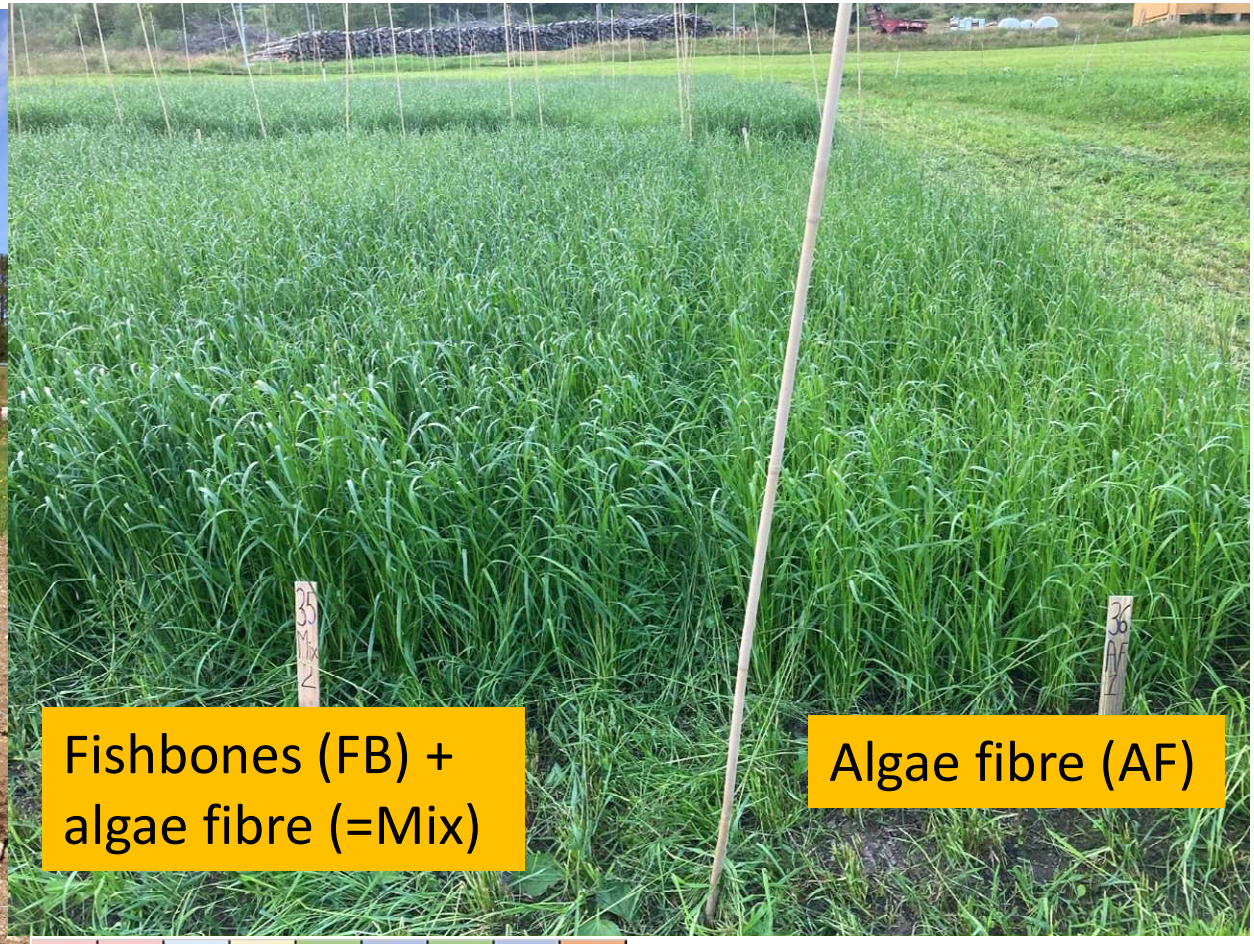
Field experiments with leek, oats and ryegrass
Residual effects measured in ley, oats and potatoes



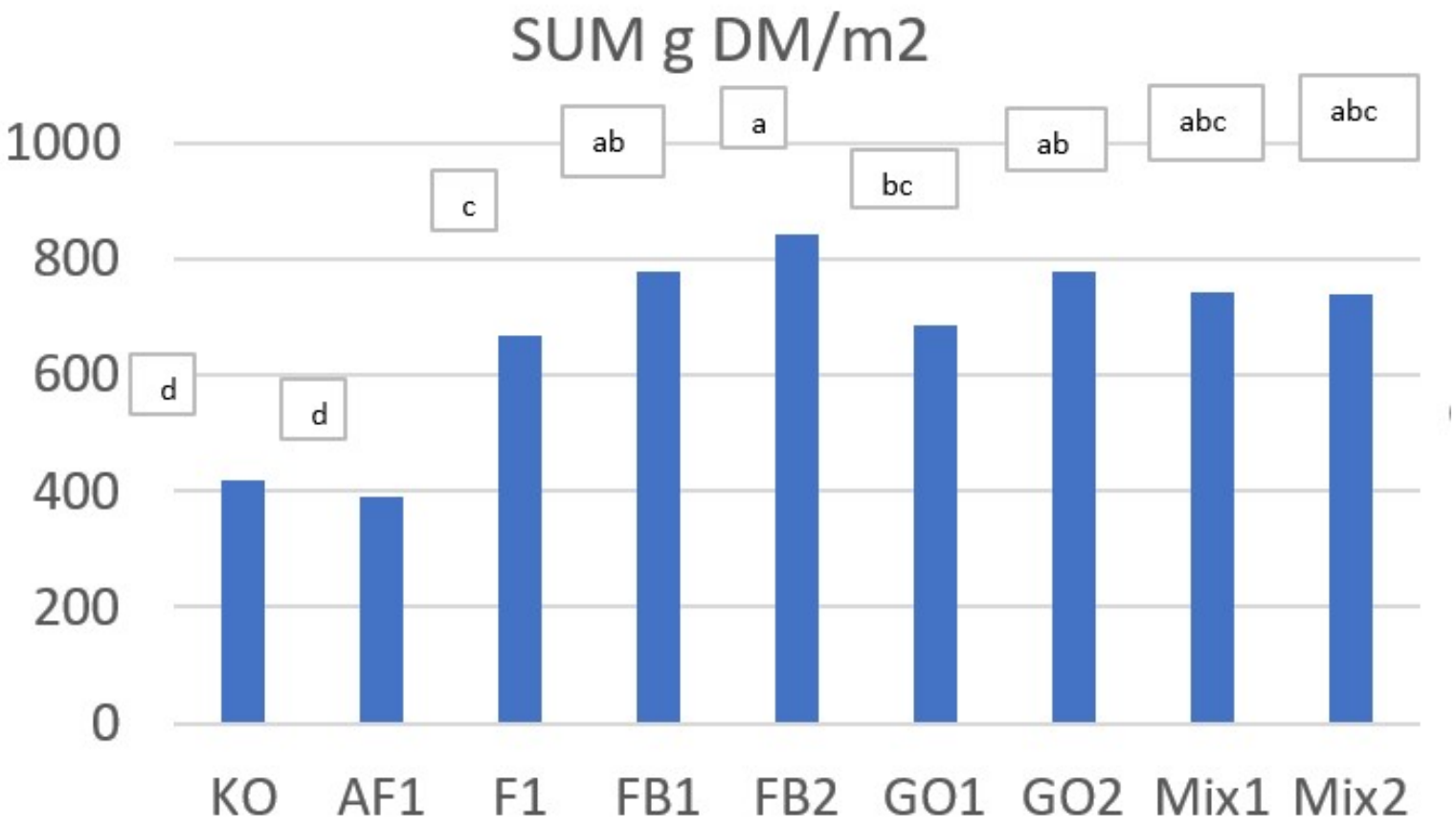
Fishbones (FB) + algae fibre (=Mix)

Algae fibre (AF)

Mix 2	Mix	F	K0	GO 2	FB	GO	FB 2	AF
Mix	F	Mix 2	FB	GO 2	FB 2	GO	AF	K0
AF	FB 2	Mix	FB	GO 2	F	Mix 2	K0	GO
GO	K0	F	GO 2	FB	FB 2	Mix	Mix 2	AF

GO= poultry manure
K0 = no fertiliser

Experiment with ryegrass, sum of 4 cuts 2020, yields 4 - 8 t DM/ha



Poor growth effect of algae fibre

Immediate growth effect of fish residues

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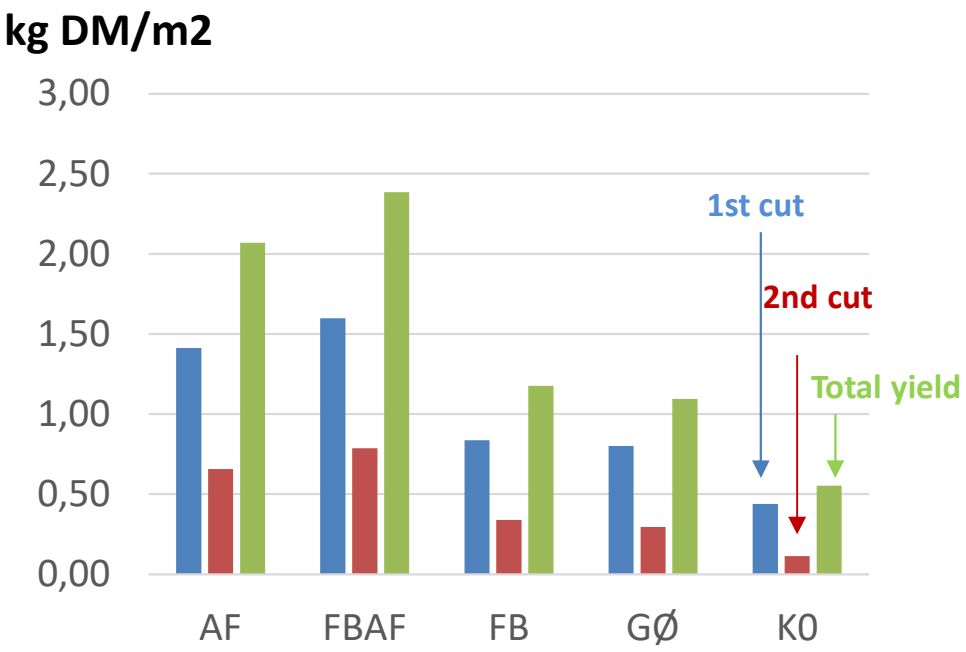
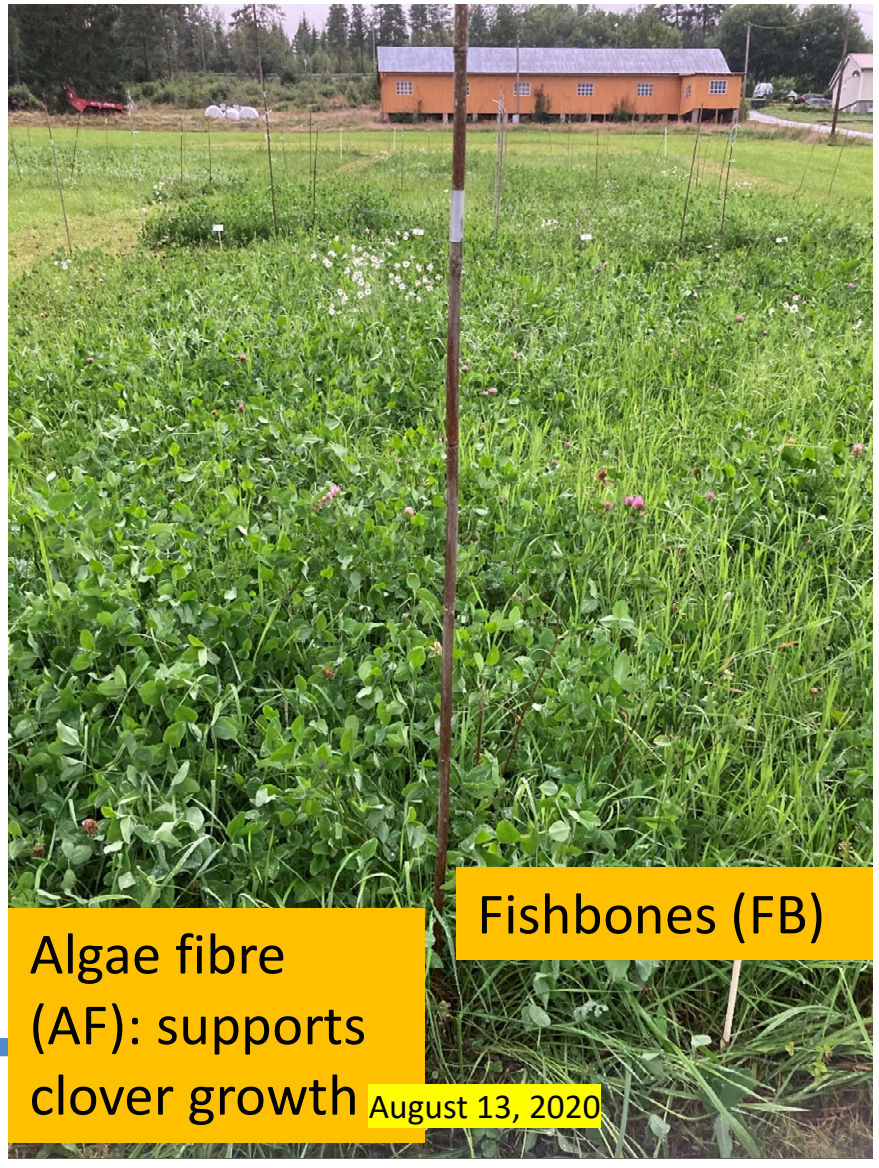
Experiment with oats followed by perennial ley 2019-2021

Residual effects in 2nd year ley, 2021



Fertilisers applied in 2019

AF	Mix	FB	GO	K0
GO	K0	AF	Mix	FB
AF	FB	K0	Mix	GO
K0	AF	FB	GO	Mix



Summarising yield effects

- Immediate growth effect of fish residues
- Slow growth effect of algae fibre, but high residual effect over more than one season
- Compiled (Mix), comparable yields and better residual effect than found for commercial fertiliser product (poultry manure)

Challenges to solve:

Balancing nutrient contents, finding raw materials and investors, processing, stabilisation, distribution….

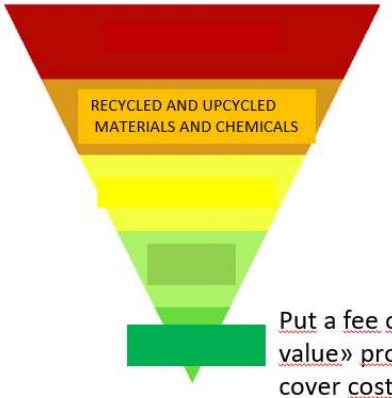
More challenges: potentially toxic elements

Potentially toxic element, mg/kg TS	Algae fibre	Acid-conserved fish bones	Grinded fresh fish bones	Limit in EU regulation Annex 1	Poultry manure «Green Organic»
As	33	1.3	6.9	No limit in Ann. 1 General EU reguletion 40?	0.15
Cd	0.9	<0.10	0.02	0.7	<0.1
Cr	3.8	<0.3	0.68	70	4
Cu	9.4	7.3	1.8	70	23
Hg	0.08	0.09	<0.7	0.4	0.01
Ni	<1.5	<1.5	2.1	25	1.6
Pb	<0.3	<0.3	0.34	45	0.71
Zn	94	100	67	200	170

More challenges – mineral balance- feed quality

- Fish bones = N, P, Ca fertiliser; not well balanced for crop needs
- Horticulture or meadow purpose? (early spring applicaton)
- Algae fibre has high concentrations of K and Na, what about feed quality? Ruminants need high proportion of Ca, Mg in the feed

Challenges – accessability, logistics

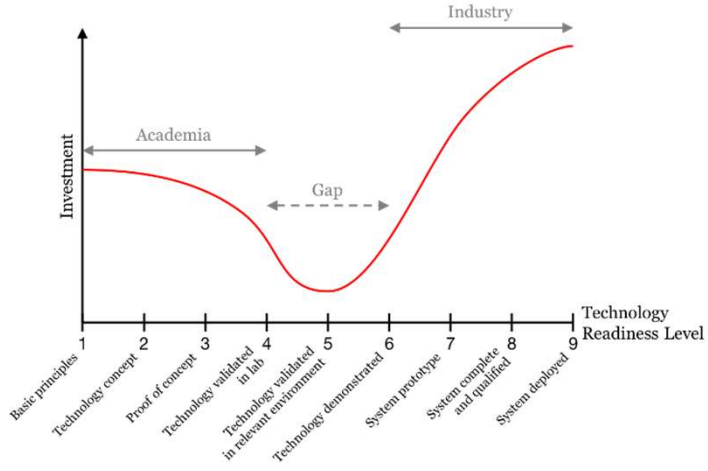


Put a fee on «high-value» products to cover costs for a complete utilisation?

- Competition for residual materials: From gate fee to purchase
- Industry will always search for products with higher profits
- Long distance from sea to farmland; two highly different cultures
- Lots of practical issues still to be solved (innovational «valley of death»)

Good fishing places are top secret
……and nobody sees what the sea hides

Agricultural practice is visible for all



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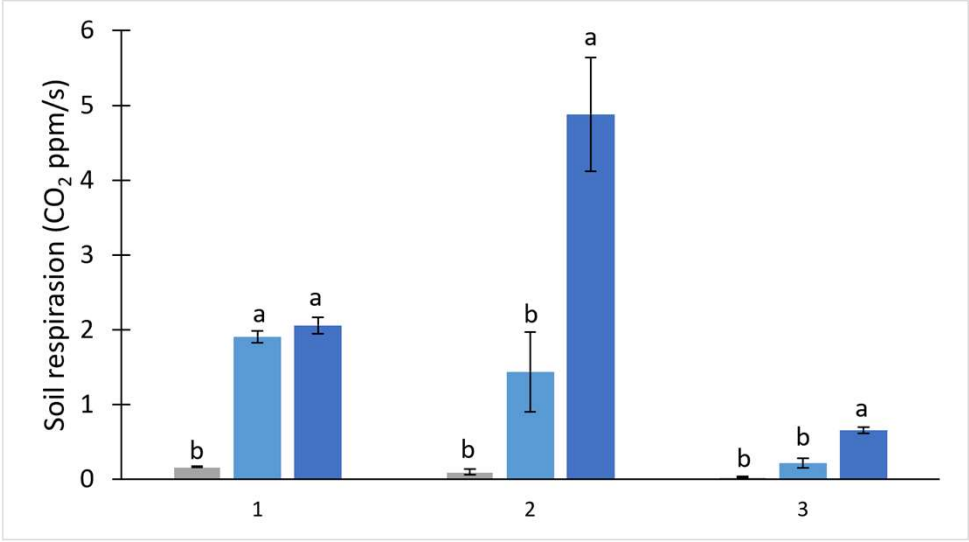
Recent and future research: soil health, biology and C sequestration

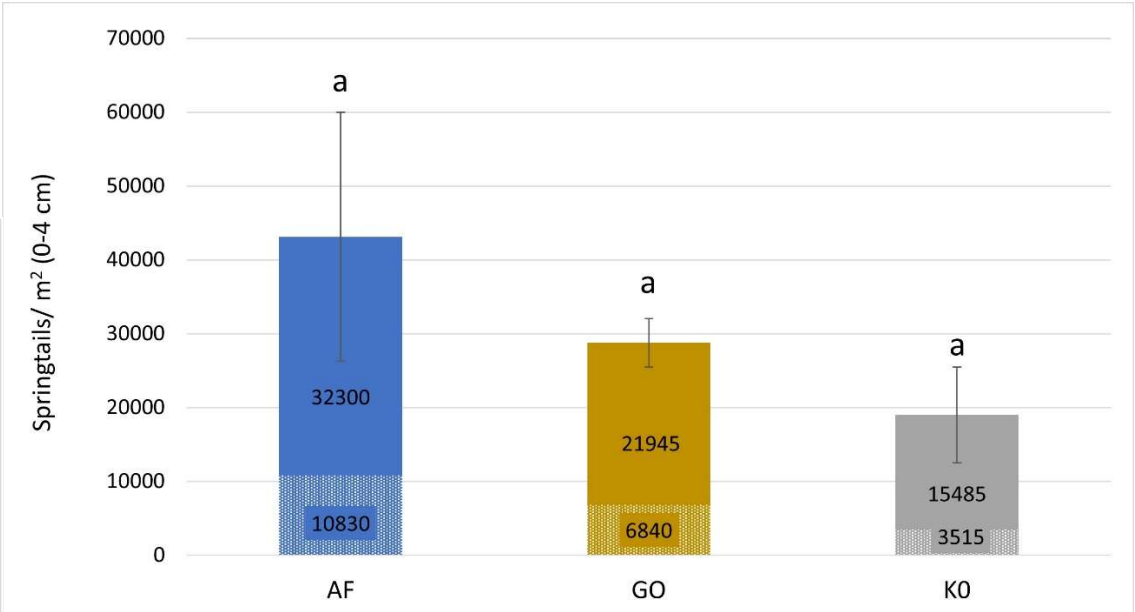
Algae fibre applied in spring 2019 or 2020 did not increase soil organic matter in fall 2020

Algae fibre increases soil respiration: easily decomposed



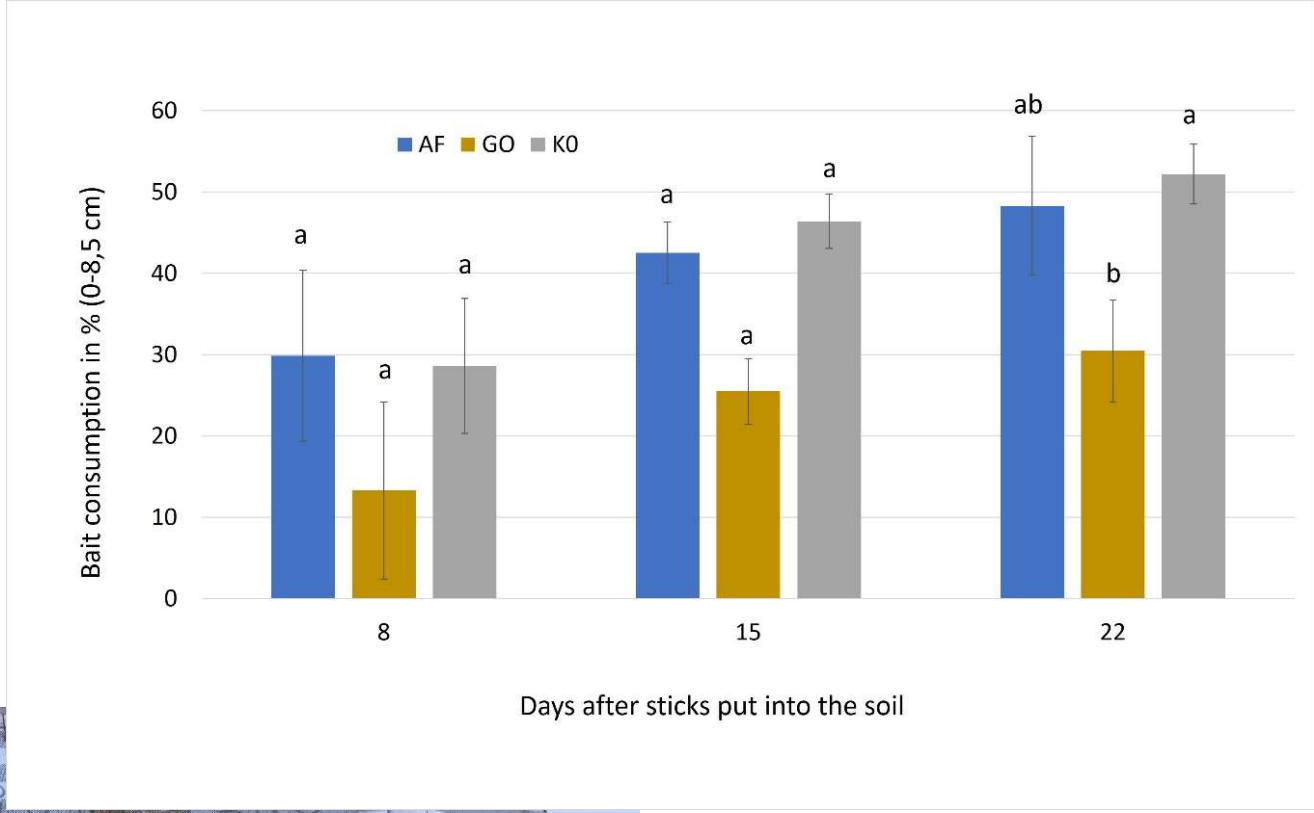
Soil respiration in soil mixed with 5%, 20% or 0% (by volume) of algae fibre, measured over 2 months

Algae fibre applied in spring 2019 increased density of springtails in May 2021



Bait lamina test for soil biological activity

Ley established with fertilisation in 2019, studied in May 2021



More activity in non-fertilised soil and after algae fibre

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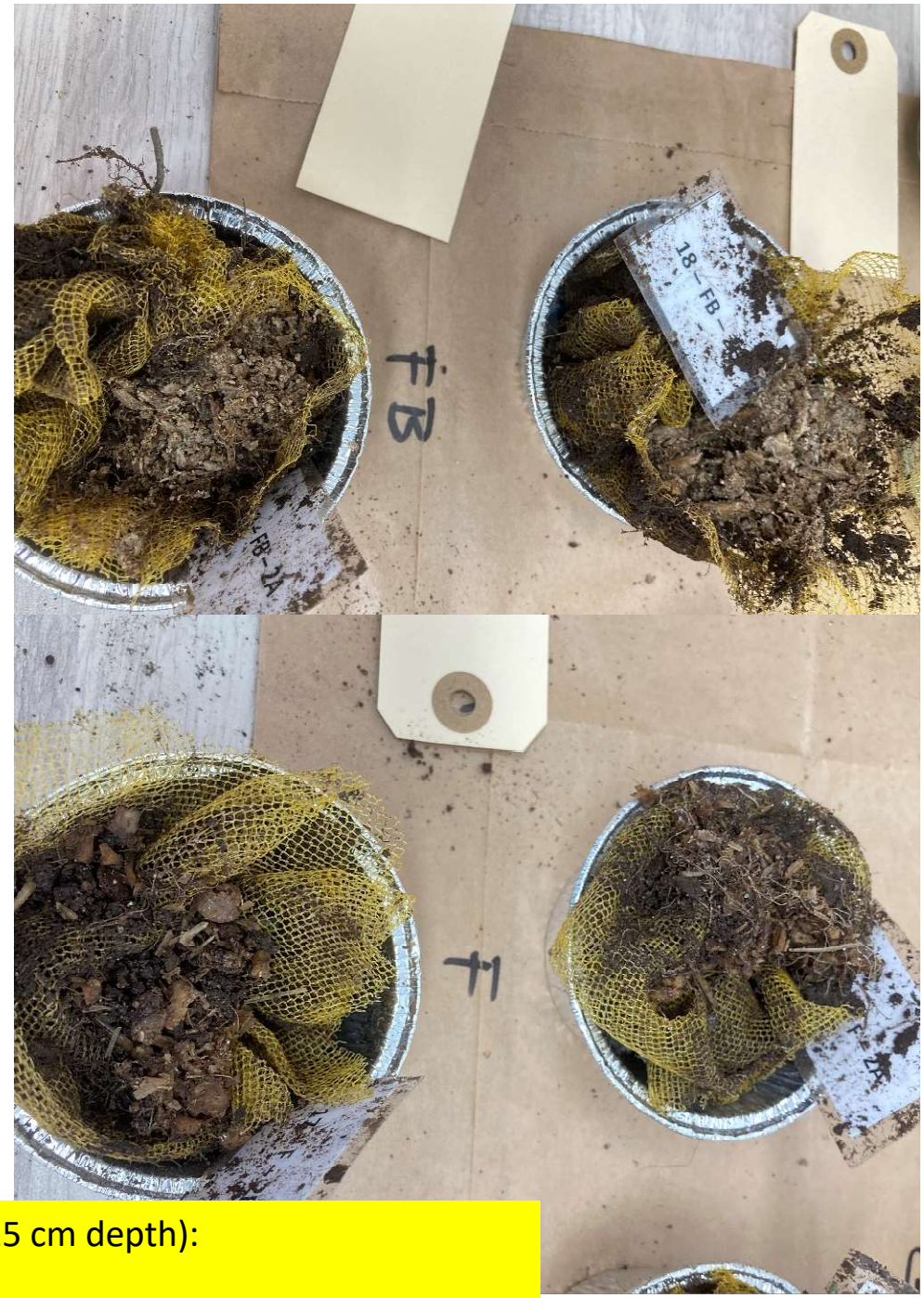
Fresh material of fish very popular among soil fauna



August 18, 2020, after 2 months in topsoil (ca. 15 cm depth):
- algae fibre (AF) still lot of material present
- acidified fishbones (FB) more material present than for fresh FB
- fresh fishbones (F) many insects and larvae in July, «pure bones» on August 18

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Soil health includes soil fertility, and we need bio-based fertilisers

Springtails from NORSØK soil

- All soil-dwelling organisms need nutrients, not just crop plants
- For decomposition and nutrient cycling in soil, we still have a lot to reveal and understand
- Fertilisers from the sea is nothing new, but needs adaptation to modern agriculture
- Rapidly increasing prices on fertilisers and urgent need for better management of slowly renewable resources call for recycling of nutrients
- Many materials are available, but more work required to find optimal technologies for processing, distribution and application

Dried fish-heads ready for producing «guano», Northern Norway 1916

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