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Trace element supplementation for stable food waste digestion

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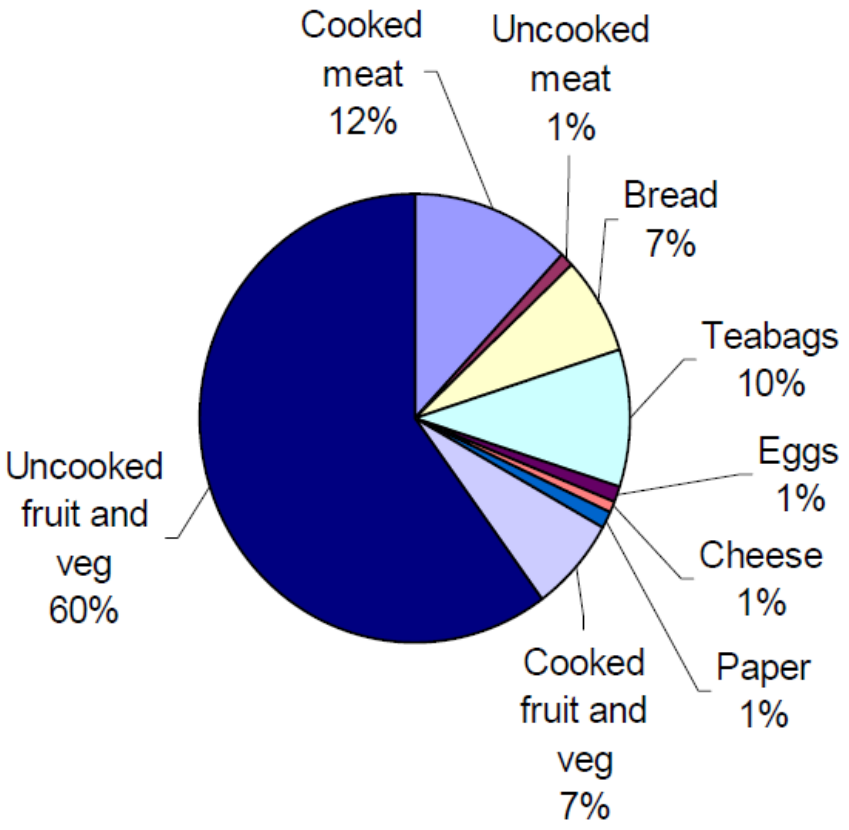
Food waste


Cooked meat 12%
Uncooked meat 1%
Bread 7%
Teabags 10%
Eggs 1%
Cheese 1%
Paper 1%
Cooked fruit and veg 7%
Uncooked fruit and veg 60%

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Laboratory digesters

CSTR-type digesters:

2-litre

5-litre

40-litre

100-litre

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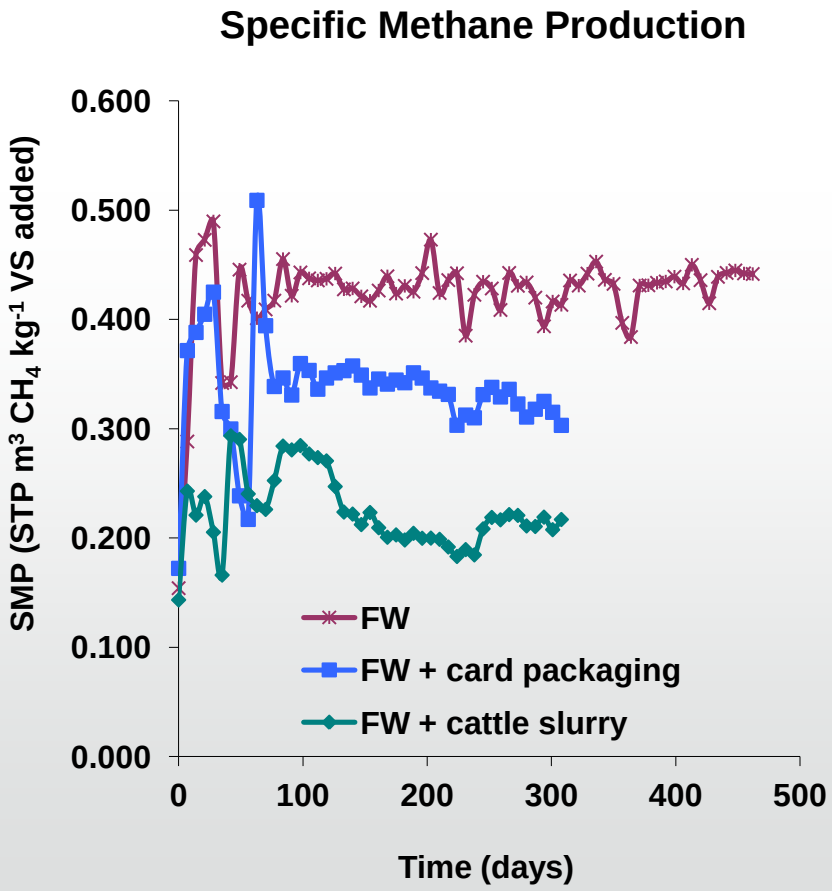
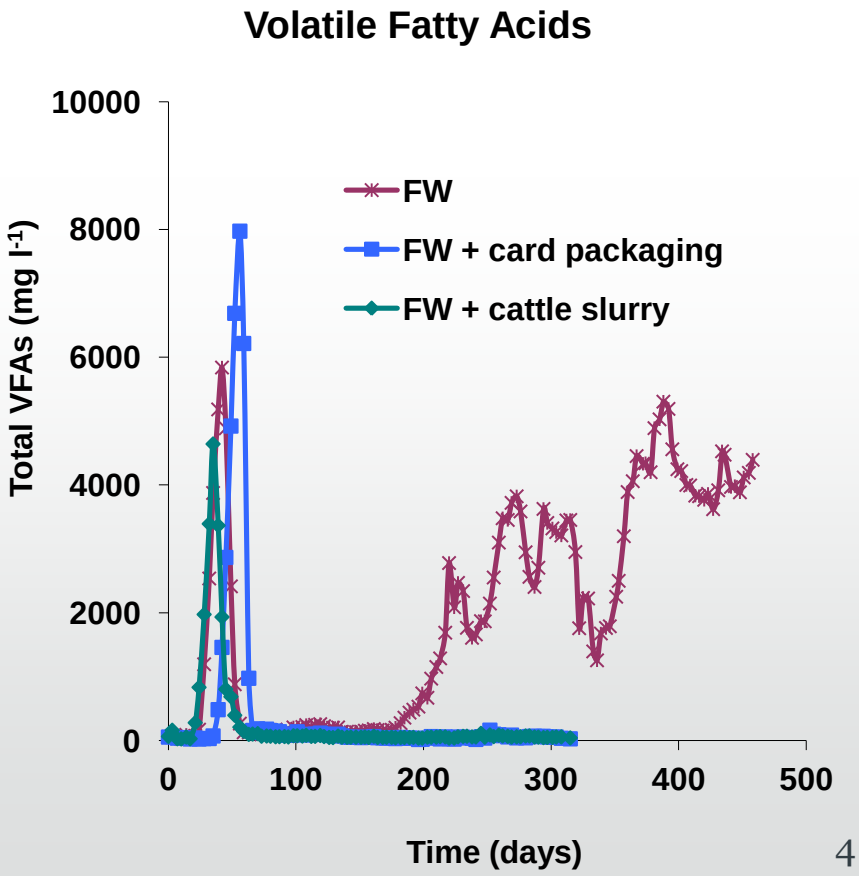
Mesophilic food waste digestion performance

Inoculum: sewage sludge digestate; **Temperature:** 36±1 ° C; **Organic loading rate:** 2 kg VS m^{-3} d^{-1}





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Stable operation of food waste digestion - Trace element supplementation

Aim - Optimising trace element supplementation strategy

- *Distinguish essential trace elements for stable food waste digestion*
- *Identify optimal trace element supplementation strength*

Research approaches

- *Batch flask trials for screening purpose*
- *Semi-continuous digester operation to monitor the long-term effect*

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Batch screening tests

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Fractional factorial design

Run	Pattern	Co	Ni	Mo	Se	Fe	W	Zn	Cu	Mn	Al	B
1	−−−−−−−−−−	-	-	-	-	-	-	-	-	-	-	-
2	−−−+++−−−−	-	-	-	Se	Fe	W	-	-	-	-	-
3	−−+−++−−−−	-	-	Mo	-	Fe	W	-	-	-	-	-
4	−−++−−−−−−	-	-	Mo	Se	-	-	-	-	-	-	-
5	−+−−+−−−−−	-	Ni	-	-	Fe	-	-	-	-	-	-
6	−+−+−+−−−−	-	Ni	-	Se	-	W	-	-	-	-	-
7	−++−−+−−−−	-	Ni	Mo	-	-	W	-	-	-	-	-
8	−++++−−−−−	-	Ni	Mo	Se	Fe	-	-	-	-	-	-
9	+−−−+−−−−−	Co	-	-	-	-	W	-	-	-	-	-
10	+−−++−−−−−	Co	-	-	Se	Fe	-	-	-	-	-	-
11	+−+−+−−−−−	Co	-	Mo	-	Fe	-	-	-	-	-	-
12	+−++−+−−−−	Co	-	Mo	Se	-	W	-	-	-	-	-
13	++−−++−−−−	Co	Ni	-	-	Fe	W	-	-	-	-	-
14	++−+−−−−−−	Co	Ni	-	Se	-	-	-	-	-	-	-
15	+++−−−−−−−	Co	Ni	Mo	-	-	-	-	-	-	-	-
16	+++++−−−−−	Co	Ni	Mo	Se	Fe	W	-	-	-	-	-
17	++++++−−−−	Co	Ni	Mo	Se	Fe	W	Zn	-	-	-	-
18	+++++++++−	Co	Ni	Mo	Se	Fe	W	Zn	Cu	Mn	-	-
19	++++++++++	Co	Ni	Mo	Se	Fe	W	Zn	Cu	Mn	Al	B

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Trace element (TE) concentrations

Essential element	Compound used	Trace element concentration (mg l^{-1})	
		Supplemented at the beginning of the tests	Existing in the test digestate
Cobalt (Co)	$CoCl_2 \cdot 6H_2O$	1.0	0.083
Nickel (Ni)	$NiCl_2 \cdot 6H_2O$	1.0	2.9
Molybdenum (Mo)	$(NH_4)_6Mo_7O_{24} \cdot 4H_2O$	0.2	0.29
Selenium (Se)	Na_2SeO_3	0.2	0.050
Tungsten (W)	$Na_2WO_4 \cdot 2H_2O$	0.2	<0.035
Iron (Fe)	$FeCl_2 \cdot 4H_2O$	5.0	173.7
Zinc (Zn)	$ZnCl_2$	0.2	8.11
Copper (Cu)	$CuCl_2 \cdot 2H_2O$	0.1	5.75
Manganese (Mn)	$MnCl_2 \cdot 4H_2O$	1.0	18.5
Aluminium (Al)	$AlCl_3 \cdot 6H_2O$	0.1	63.3
Boron (B)	H_3BO_3	0.1	2.5

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Experimental set up

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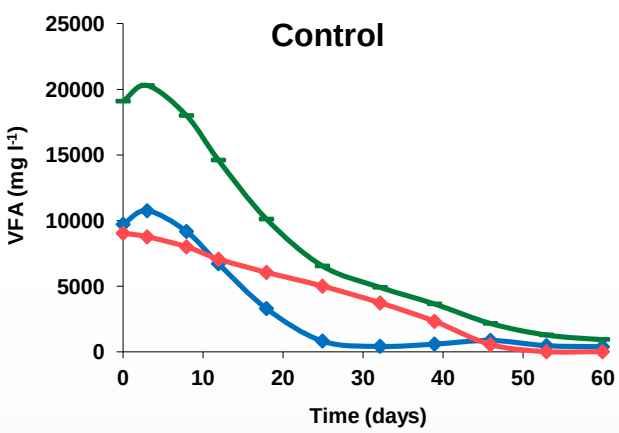
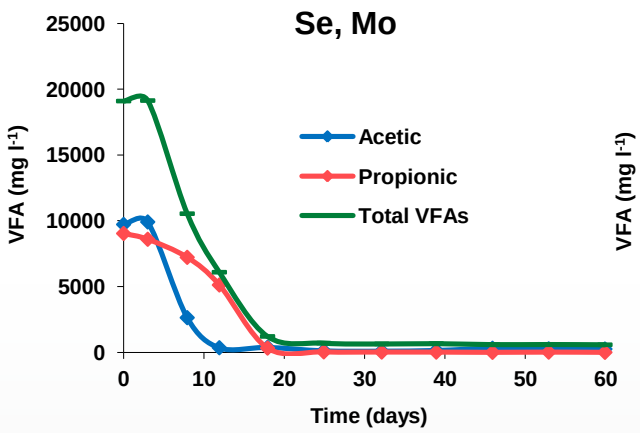
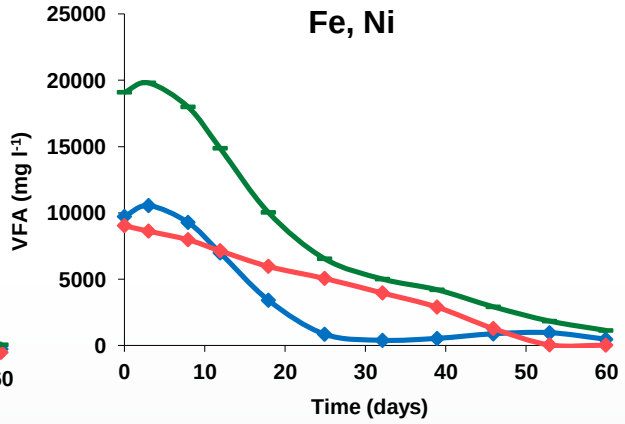
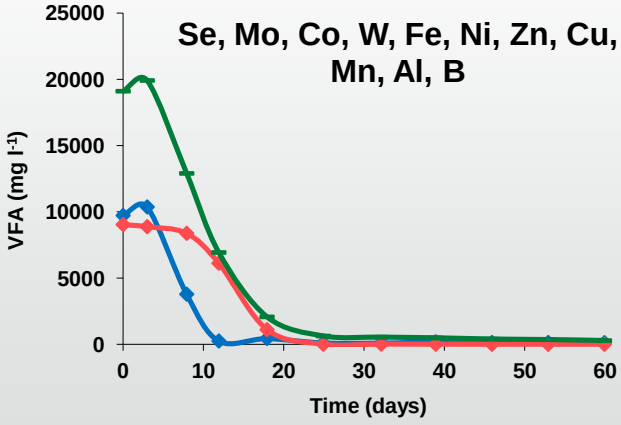
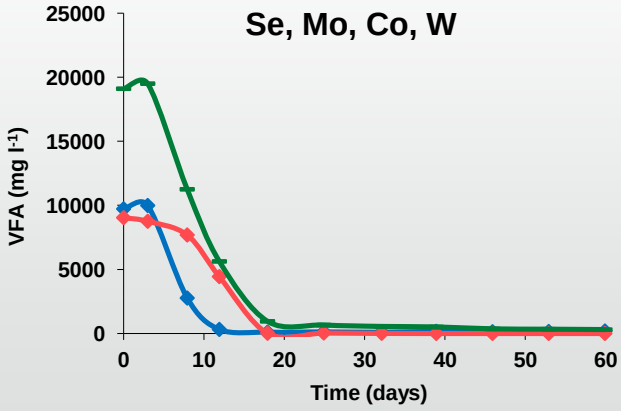
VFA degradation profiles

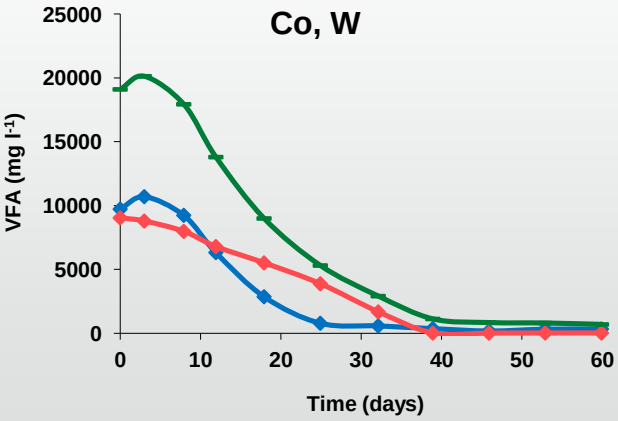












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Essential trace elements for food waste digestion

Tier	Trace element	Compound		Dosing strength (g tonne^{-1})
1st	Selenium (Se)		Na_2SeO_3	0.2
	Molybdenum (Mo)		$(NH_4)_6Mo_7O_{24}\cdot 4H_2O$	0.2
2nd	Cobalt (Co)		$CoCl_2\cdot 6H_2O$	1.0
	Tungsten (W)		$Na_2WO_4\cdot 2H_2O$	0.2
3rd	Iron (Fe)		$FeCl_2\cdot 4H_2O$	5.0
	Nickel (Ni)		$NiCl_2\cdot 6H_2O$	1.0
4th	Zinc (Zn)		$ZnCl_2$	0.2
	Copper (Cu)		$CuCl_2\cdot 2H_2O$	0.1
	Manganese (Mn)		$MnCl_2\cdot 4H_2O$	1.0
	Aluminium (Al)		$AlCl_3\cdot 6H_2O$	0.1
	Boron (B)		H_3BO_3	0.1

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Semi-continuous trials

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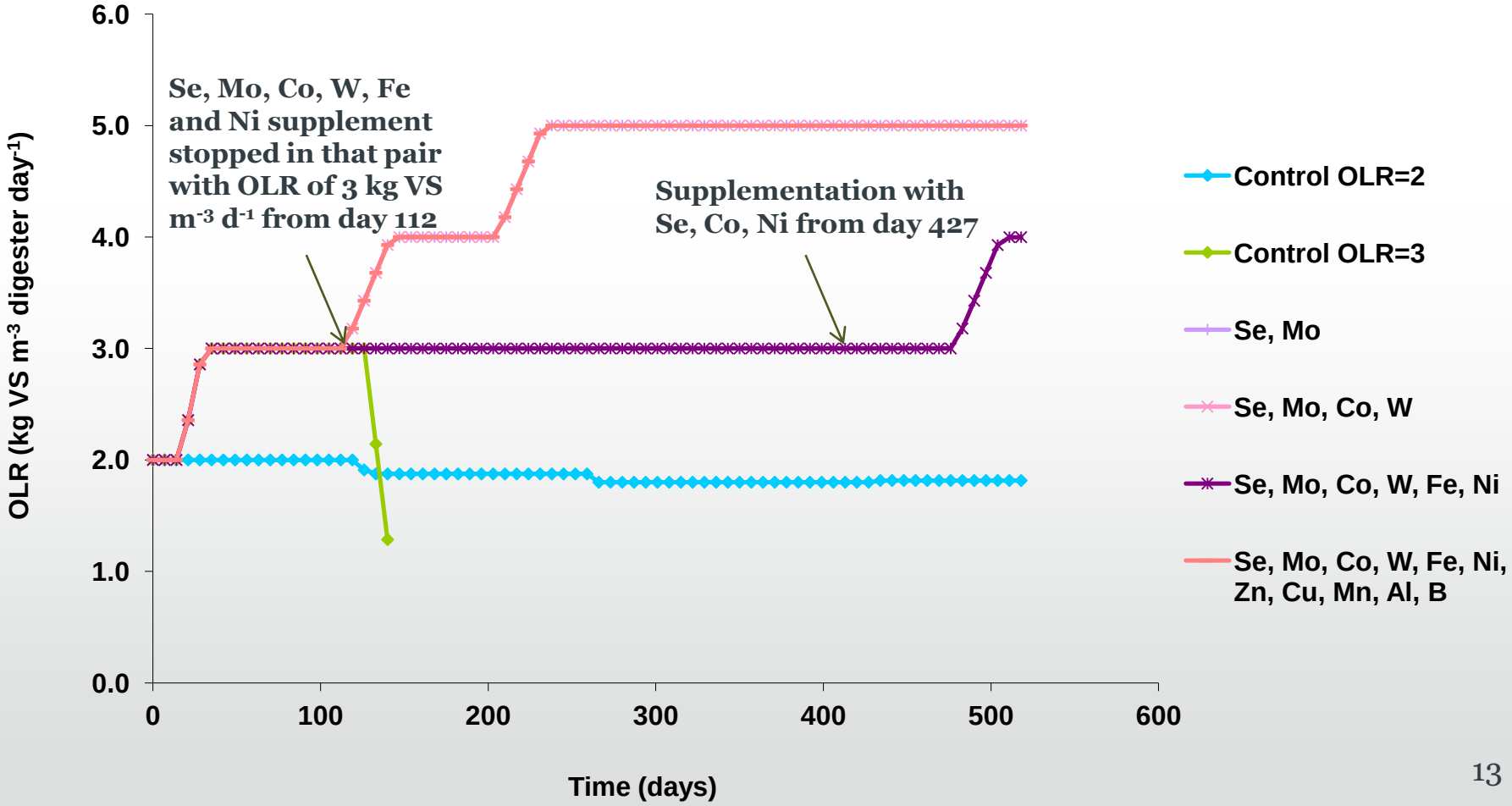
Organic loading rate (OLR)



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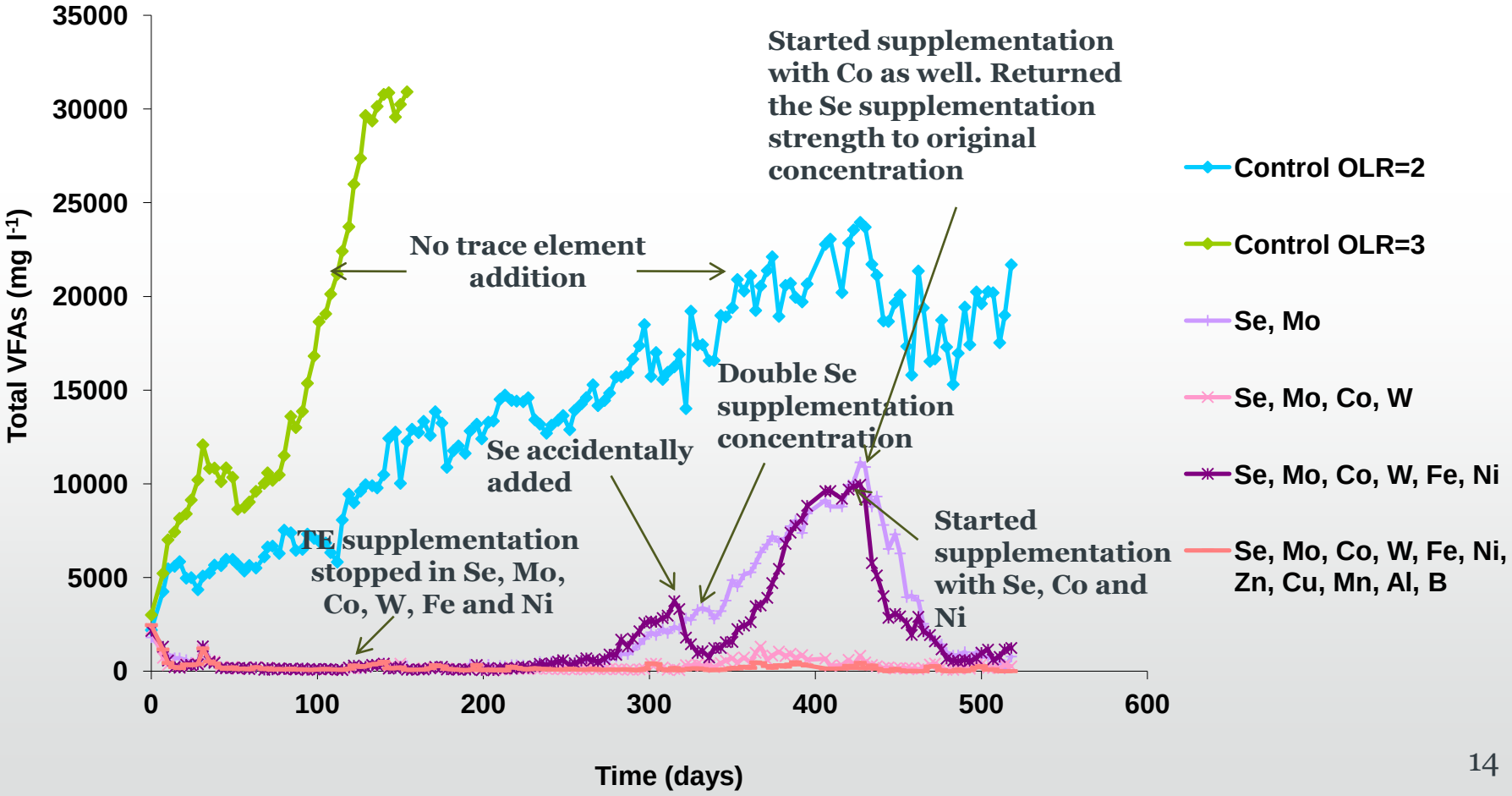
Volatile fatty acids (VFA) profiles



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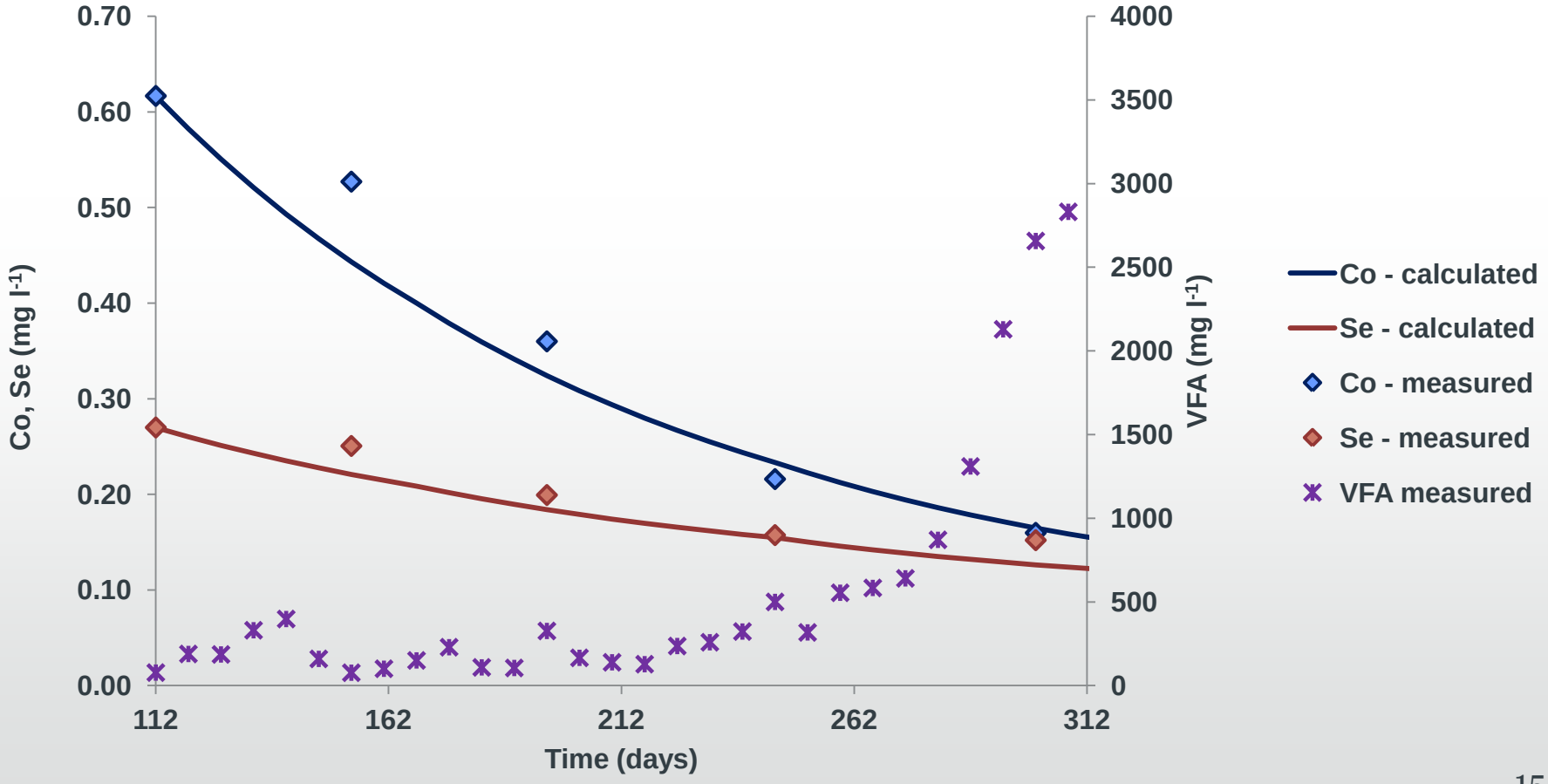
Co and Se dilute-out curves – VFA profile



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TE required *vs* TE in the food waste

	Minimum requirement at a moderate loading rate	Hackney, London	Eastleigh, Hampshire	Ludlow, Shropshire	Luton, South Bedfordshire
Cobalt (Co)	**0.22**	0.09 ± 0.05	0.02 ± 0.01	0.02 ± 0.00	< 0.06
Selenium (Se)	**0.16**	0.10 ± 0.08	0.03 ± 0.00	0.28 ± 0.14	< 0.07
Total Kjeldahl Nitrogen (TKN)		8100	7500	7400	8100

Unit: mg kg^{-1} fresh matter

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FISH analysis on methanogenic community structure

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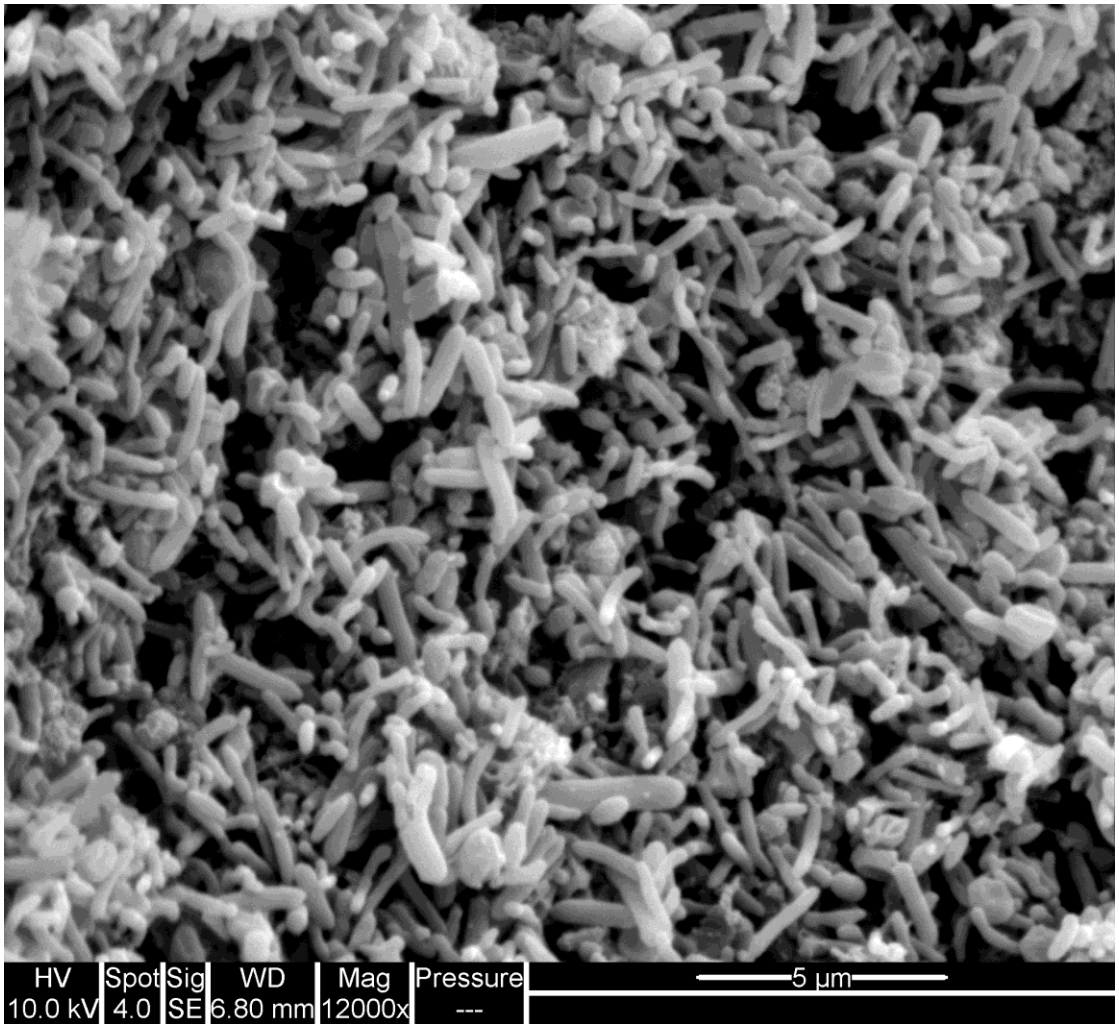
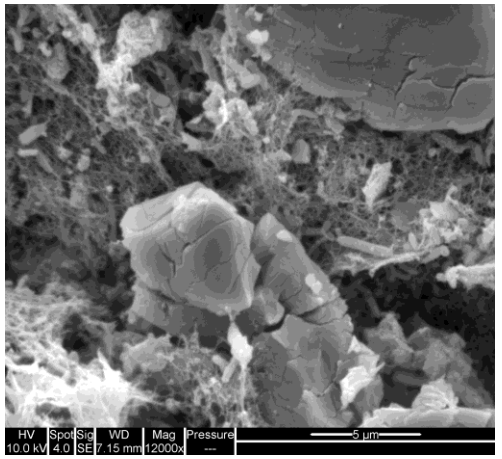
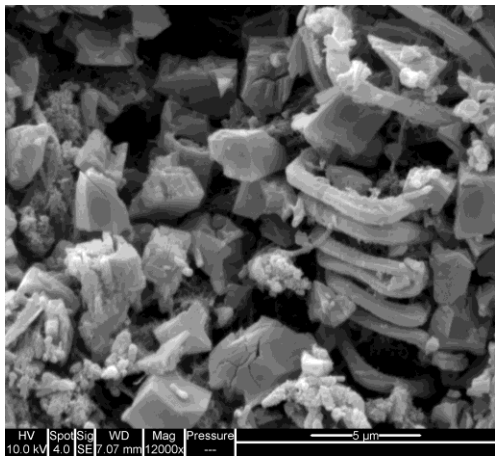
Density gradient centrifugation using Nycodenz







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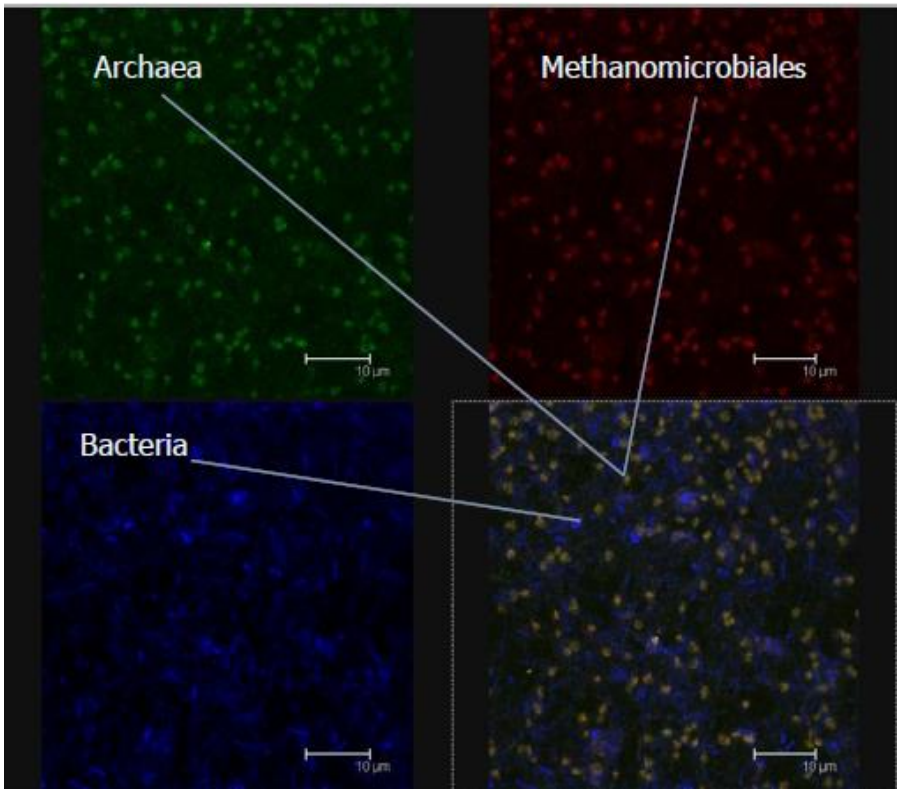
FISH images



Probe name	Target group	Fluoro-chrome	Formamide (%)
EUB338	*Bacteria (most)*	Cy5	20~50
EUB338+	*Bacteria (remaining)*	Cy5	20~50
ARC915	*Archaea*	6-Fam	20~50
MX825	*Methanosaetaceae*	Cy3	50
MS1414	*Methanosarcinaceae*	Cy3	50
hMS1395	MS1414-helper	-	50
hMS1480	MS1414-helper	-	50
MSMX860	*Methanosarcinales*	Cy5	45
MG1200	*Methanomicrobiales*	Cy3	20
MB1174	*Methanobacteriales*	Cy3	45
MC1109	*Methanococcales*	Cy3	45

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Conclusions

Conclusions

Trace elements

- *Selenium and cobalt are the key TE needed for the long-term stability of food waste digesters, but are likely to be lacking in the food waste produced in the UK. We are still not sure about Mo and W.*

Digester operation

- *Following proper TE supplementation strategy, food waste digesters can be operated stably with low VFA concentrations at an organic loading rate of 5 kg VS m^{-3} d^{-1} with a volumetric biogas production of 3.8 STP m^3 m^{-3} d^{-1} and specific biogas production of 0.76 STP m^3 kg^{-1} VS.*

Methanogenic community structure

- *Methanogenic population was comprised exclusively of members of the order Methanomicrobiales, according to FISH analysis.*

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Thank you for your attention