DPTC SUSTAINABILITY RESEARCH

CIRCULAR DAIRY ECONOMY: HARNESSING OPPORTUNITIES FOR A SUSTAINABLE FUTURE

Odourless controlled release phosphate fertilizer from dairy sludge

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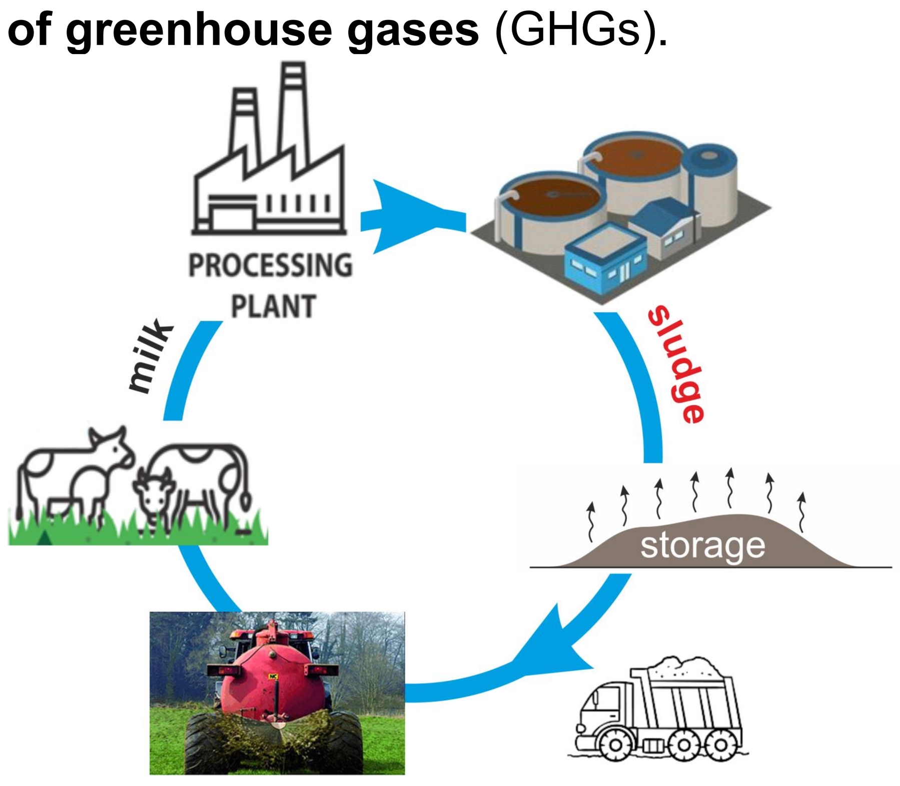
Background / Industry Relevance / Context of circularity

Each m^3 of milk processed in dairy companies produces 2.71 m^3 of effluent[1]. As a result of effluent treatment large volumes of sludge is produced (per m^3 of milk processed WWTP in dairy plant produces up to 17.45 kg sludge). Sludge is separated by from the "clean" wastewater that is discharge to a local water body. In 2015 126,718 tonnes (wet weight) of dairy processing sludge (DPS) was produced. DPS is reach in **plant nutrients phosphorus** (P), **nitrogen** (N) and **organic matter** but it has very low content of heavy metals. The high N content of DPS imposes limits due to EU Nitrates Directive 91/676/EEC. To limit loss of nutrients to both surface and ground water biosolids should not be applied to land if rain is forecast within 48h, the soil is waterlogged, flooded, snow covered or frozen. This limits land application during the winter and crop cover precludes the application in summer. Thus, **storage of sludge is required** for extended periods of time while it is produced continuously. When sludge is stored, the organic matter decomposes causing **formation of greenhouse gases** (GHGs).

Separation of sludge from wastewater is the primary challenge, mechanical dewatering can reduce **moisture** only **up to 85 %**. Therefore, nutrients are very diluted and **transport costs of huge amount of ballast water** are high. As a result, DPS is commonly spread on lands in the vicinity of the dairy plants.



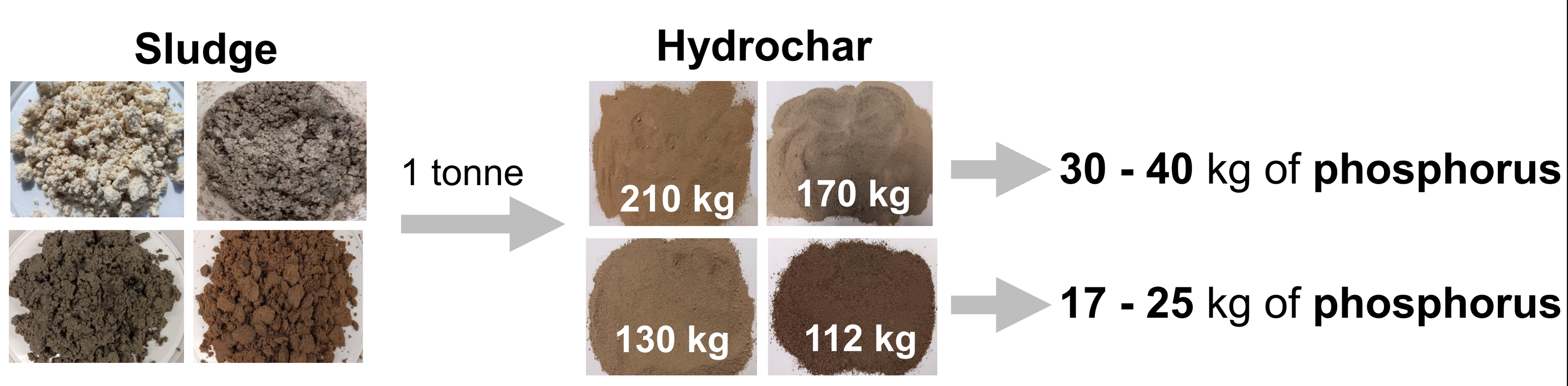
1 Ashekuzzaman, S.M., Forrestal, P., Richards, K., Fenton, O., 2019. Dairy industry derived wastewater treatment sludge: Generation, type and characterization of nutrients and metals for agricultural reuse. Journal of Cleaner Production 230

Objective of Research

- This project is investigating transformation of problematic but valuable sludge stream (large volume storage required, during storage emissions of GHGs occur) into easier to store and apply fertilizer.
- Evaluate potential for valorisation of dairy sludge through hydrothermal carbonization (HTC) for **solid phosphorus fertilizer**.
- Evaluate potential for valorisation of hydrothermal carbonization process liquid product on site in WWTP.

Value provided to Industry / Circular Economy / Sustainability Goals to-date

- Produced easily dewatered hydrochars with concentrated phosphorus (and other plant nutrients), low odour, granular material easier to store, transport and spread which can qualify as fertilizer component.



Value provided to Industry / Circular Economy / Sustainability Goals to-date

- Have produced and characterised hydrochars and identified the conditions required to produce materials suitable to meet most of the criteria of the regulation (Fertilizing Products Regulation, FPR 1009/2019) as component of fertilizer.

Nutrient content in hydrochar

	BS3 200°C mass %	BS4 200°C mass %	WS1 200°C mass %	WS2 200°C mass %	Organo-mineral fertilizer mass % minimal	Inorganic fertilizer mass % minimal
C organic	29.6	25.9	7.6	-	7.5	
Total N	7.1	4.6	1.6	5.1	2	10
P_2O_5	19.6	17.0	31.7	21.0	2	12
K_2O	0.7	0.9	0.5	0.5	2	6
Sum of NP	26.7	21.6	33.3	26.1	At least 8	

Organic contaminants in hydrochars

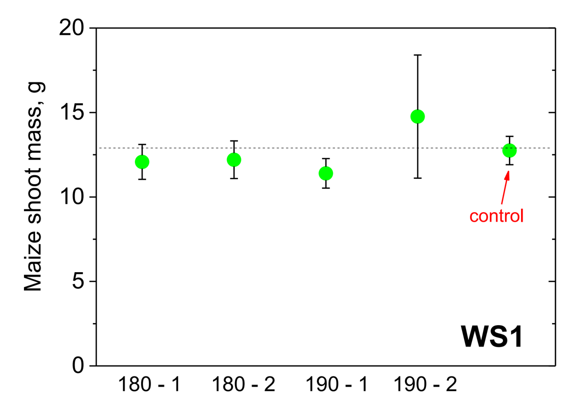
	BS3 200°C	BS4 200°C	WS1 200°C	WS2 200°C	Fertiliser maximal
H/C	1.4	2.0	1.2	1.3	< 0.7
PAH(16)*	2.1	2.4	-	-	6 mg/kg
PCDD/F**	0.55	1.3	-	0.86	20 ng/kg
ndl-PCB***	0.00087	0.0025	-	0.0004	0.8 mg/kg
Cl^-	0.6	1.3	0.1	1.1	30 g/kg

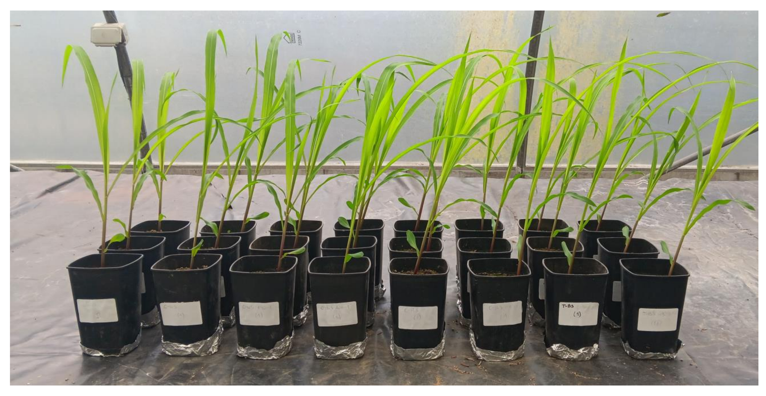
Heavy metals content in hydrochars

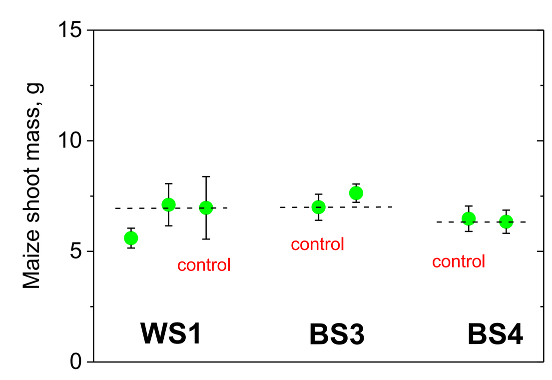
	BS3 200°C	BS4 200°C	WS1 200°C	WS2 200°C	Fertiliser Maximal
Cd	nd	nd	nd	nd	60 mg/kg
Hg	nd	nd	nd	nd	1
Ni	23	37	10	13	50
Pb	nd	5	nd	nd	120
As	nd	nd	4	7	40
Cu	13	56	6	5	600
Zn	167	405	45	73	1500

- Short plant growth trial (4 weeks) with maize demonstrated that hydrochars behave similarly in terms of plant growth to sludge (transformation of phosphorus into slow-release fertilizer, for sludge with high calcium content).

Hydrochar + Urea as fertilizer



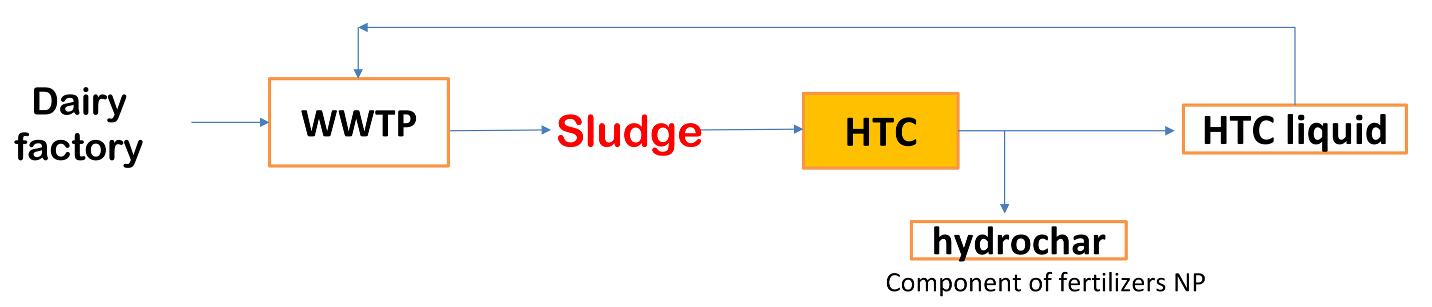




- Direct knowledge on level of plant available nutrients in sludge and hydrochars

Future Industry Impact – Advancing Dairy Processing

- If successful, an integration of HTC of dairy processing sludge would improve management practices and reduce the environmental impact while maintaining its agronomic value in the form of solid hydrochar.



- HTC reduces moisture content (mass of hydrochar is 10 – 20 % of initial sludge mass) and reduces transport cost.
- Reduced storage volume and reduced emissions of GHGs. Literature shows that the GHG emissions from the management chain of untreated DPS were as high as 359 kg $CO_{2equivalent}$, in contrast producing hydrochar from DPS reduces GHG emissions to -30 kg $CO_{2\ equivalent}$.
- Improved long term plant nutrient management (slow-release fertilizer).

Conclusions

- It is unlikely that hydrochars produced from dairy sludge will be exported. In this context the FPR 1009/2019 might not be relevant. Some national guidance / regulatory instruments are necessary for these materials to be part of a sustainable bio-fertilizer market.

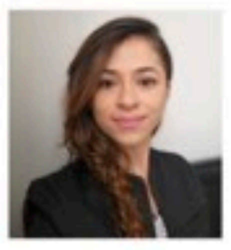
This work has been supported by Enterprise Ireland. Grant Agreement Number : TC 2020 0028.

CIRCULAR DAIRY SUMMIT 2024:

DPTC SUSTAINABILTIY RESEARCH

CIRCULAR DAIRY ECONOMY: HARNESSING OPPORTUNITIES FOR A SUSTAINABLE FUTURE

Valorisation of dairy side streams for the volatile fatty acid production



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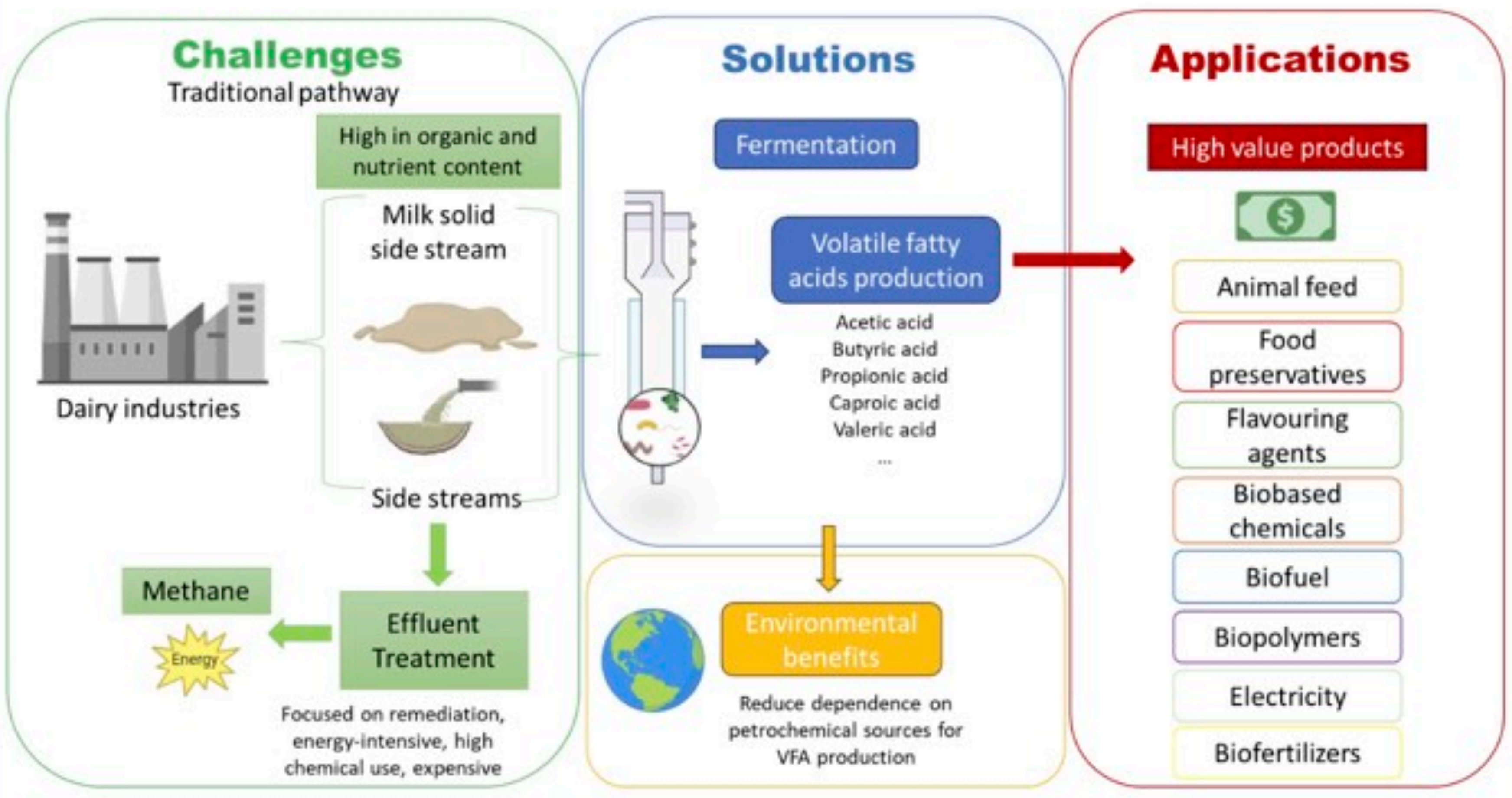


Objective of Research ★ Evaluate the potential of valorisation of side streams from dairy industries via volatile fatty acids production

Value provided to Industry

❖**Waste to Product: Fermentation of side streams from the dairy industry demonstrates significant potential for VFA production**

Table 1: Characteristics of the samples from dairy industries

Samples	pH	VS/TS ratio	COD (g/L)	C/N
MS	4.3	0.9	61.0	7.6
WP-A	1.6	0.3	2.9	7.1
WP-C	12.8	0.3	7.0	22.3
CP	4.5	0.5	11.5	13.8
		VS/TS ratio	**COD (%)**	**C/N**
SM	--	0.9	70.2	9.5
C	--	0.9	83.4	4.1

MS: Stream from milk separation, WP-A: Stream from whey powder acid, WP-C: Stream from whey powder caustic, CP: Stream from the cleaning process, SM: Skim milk sweepings, C: Casein sweepings, VS: Volatile solids, TS: Total solids. COD: Chemical oxygen demand.

Batch fermentation

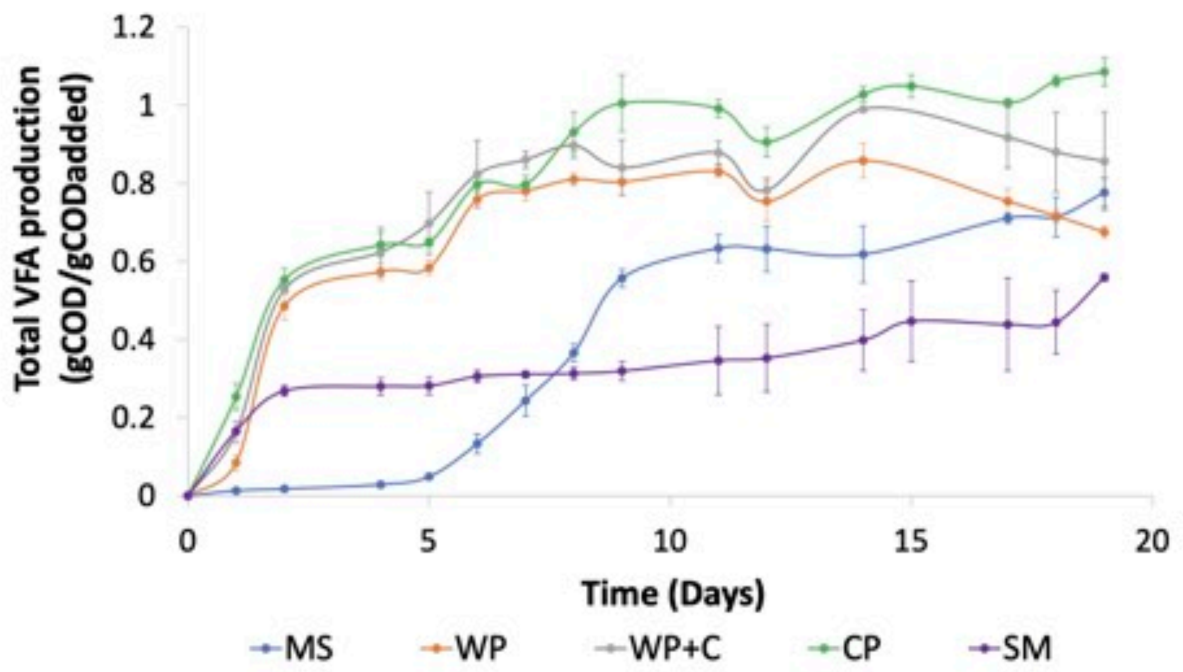


Fig. 1: VFA production in batch reactors.

VFA: Volatile fatty acids, COD: Chemical oxygen demand.

❖**Substrates Matters: The performance and parameters of fermentation are intricately linked to the unique characteristics of the side stream material.**

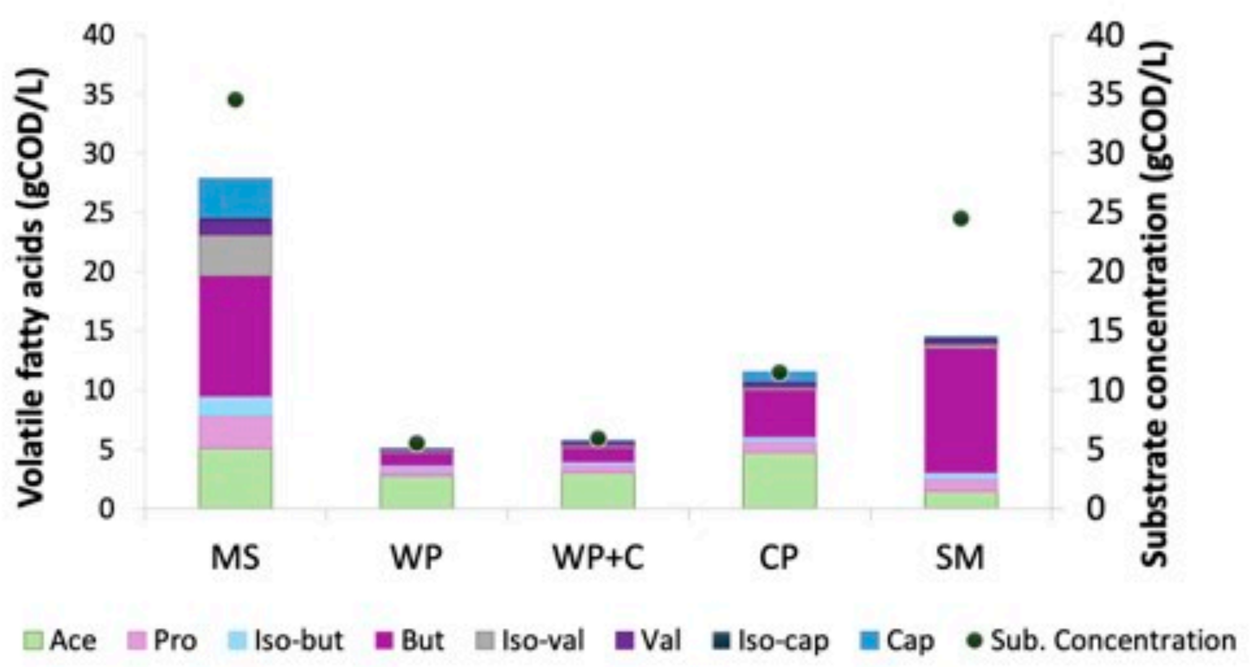


Fig. 2: Composition of the effluent after batch fermentation.

❖**Economic and Environmental Benefits: Embracing the VFA Platform not only enhances economic prospects but also offers environmental advantages, transforming the landscape of the dairy industry.**

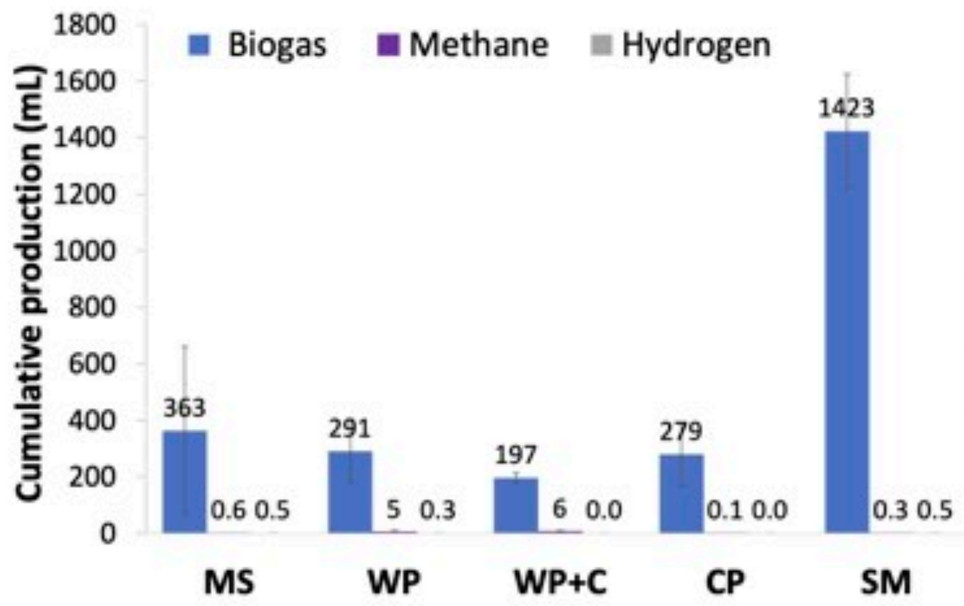


Fig. 2: Biogas, methane and hydrogen production of batch reactors.

Table 2: Batch reactors performance after 19 days of fermentation

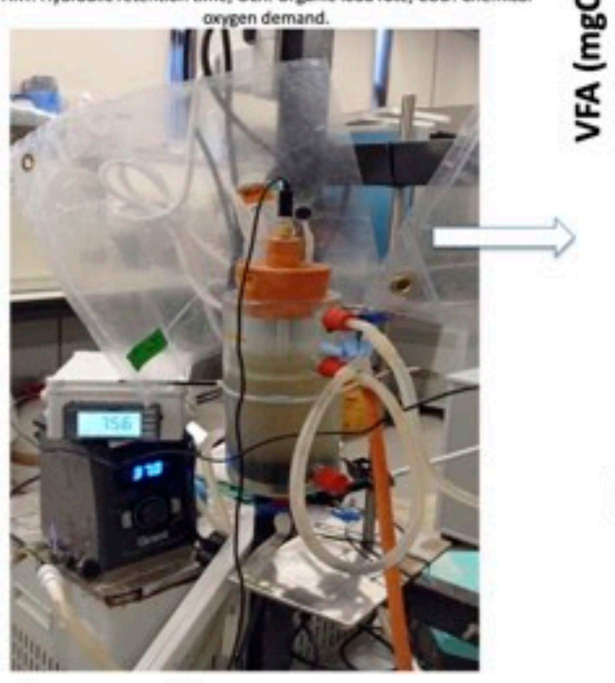
Reactors	MS	WP	WP+C	CP	SM
Proteins red. (%)	98.5	77.8	97.6	99.3	59.3
Sugars red. (%)	99.1	91.2	92.7	92.5	96.6
Final pH	5.5	7.1	6.9	4.9	3.7

❖**Optimizing the Process: By fine-tuning fermentation parameters, we enable a more efficient fermentation processes.**

Table 3: Conditions for reactors operation

Conditions	Phase 1	Phase 2
HRT (hours)	35	12
OLR (gCOD/Ld)	7.9	23.6

HRT: Hydraulic retention time, OLR: Organic load rate, COD: Chemical oxygen demand.



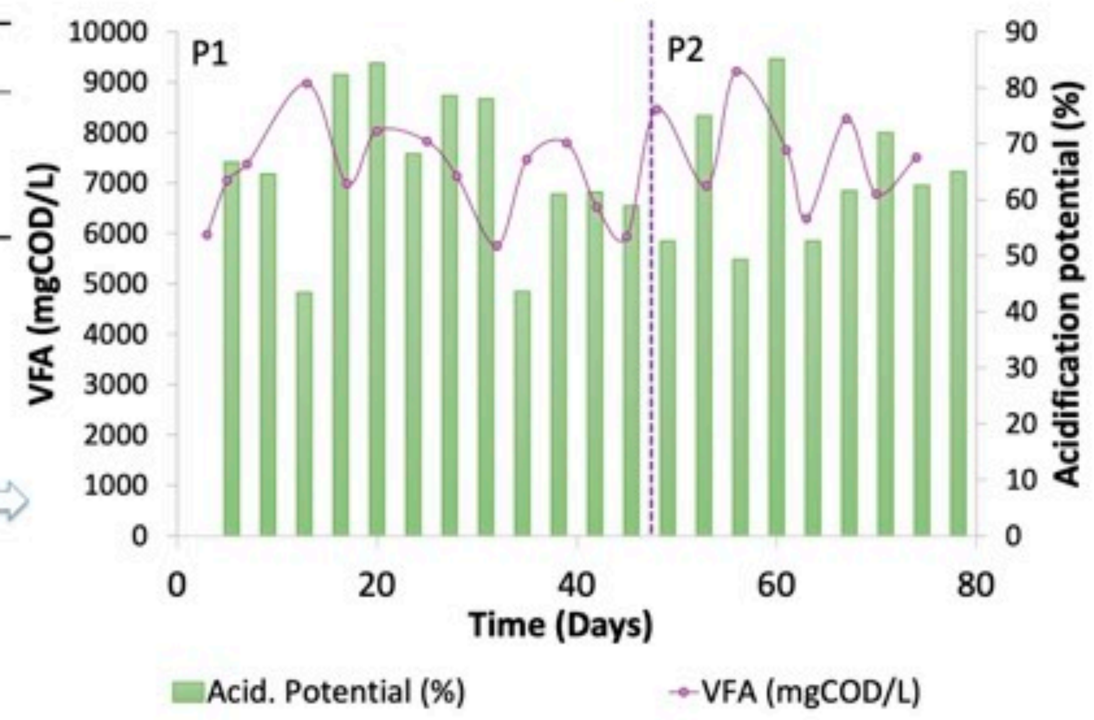


Fig. 3: VFA production and acidification potential of UASB reactors.

COD: Chemical oxygen demand, TSS: Total suspended solids.

Table 4: UASB reactors performance.

Parameters	Phase 1	Phase 2
Substrate concentration (gCOD/L)	11.3	11.8
Influent pH	5.7	5.8
Effluent pH	6.3	5.9
Influent ammonium (mg/L)	8	6
Effluent ammonium (mg/L)	147	117
TSS reduction (%)	78.4	72.0

COD: Chemical oxygen demand, TSS: Total suspended solids.

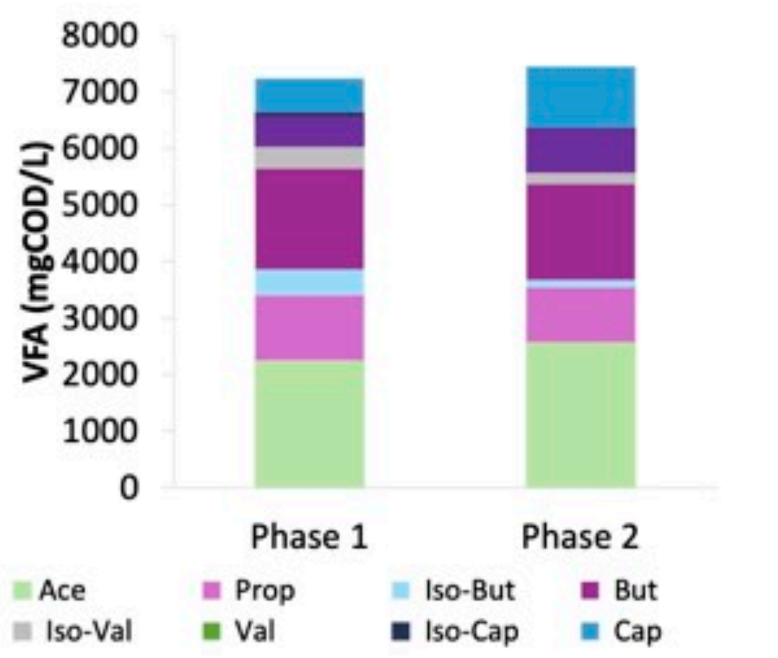


Fig. 4: Effluent composition in the UASB reactors.

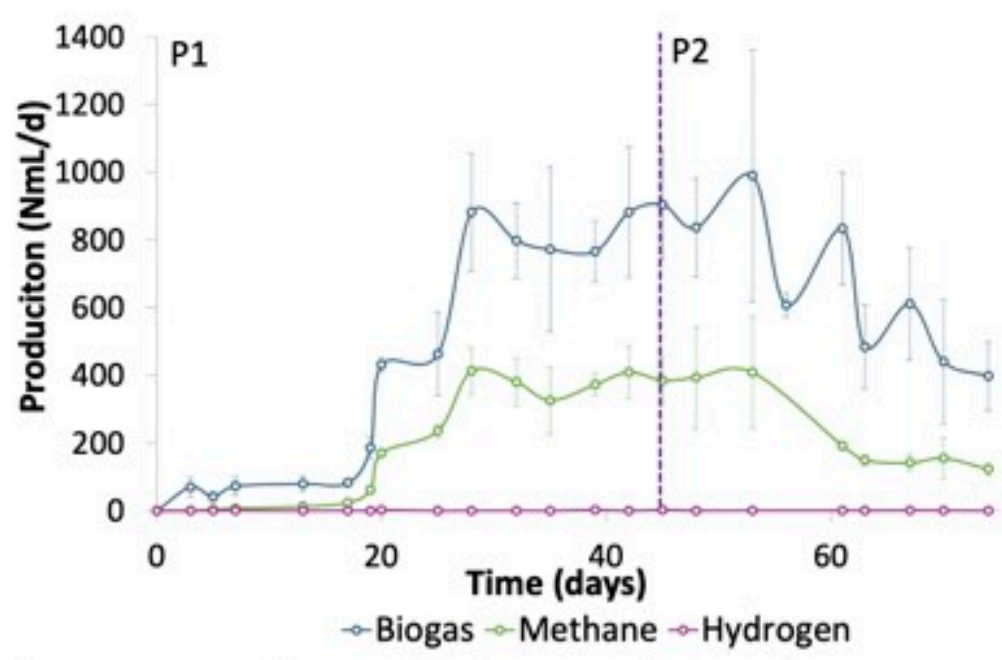
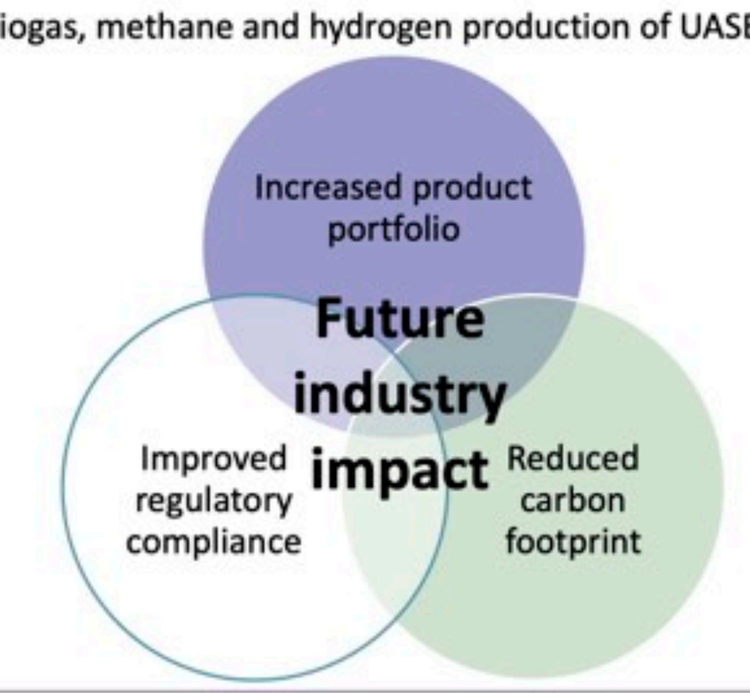


Fig. 5: Biogas, methane and hydrogen production of UASB reactors.



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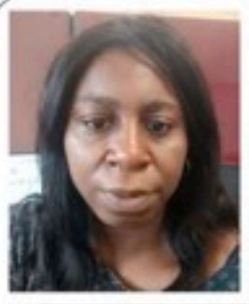
DPTC SUSTAINABILTITY RESEARCH

CIRCULAR DAIRY ECONOMY: HARNESSING OPPORTUNITIES FOR A SUSTAINABLE FUTURE

Microwave pretreatment for unlocking the value of dairy industry sludges



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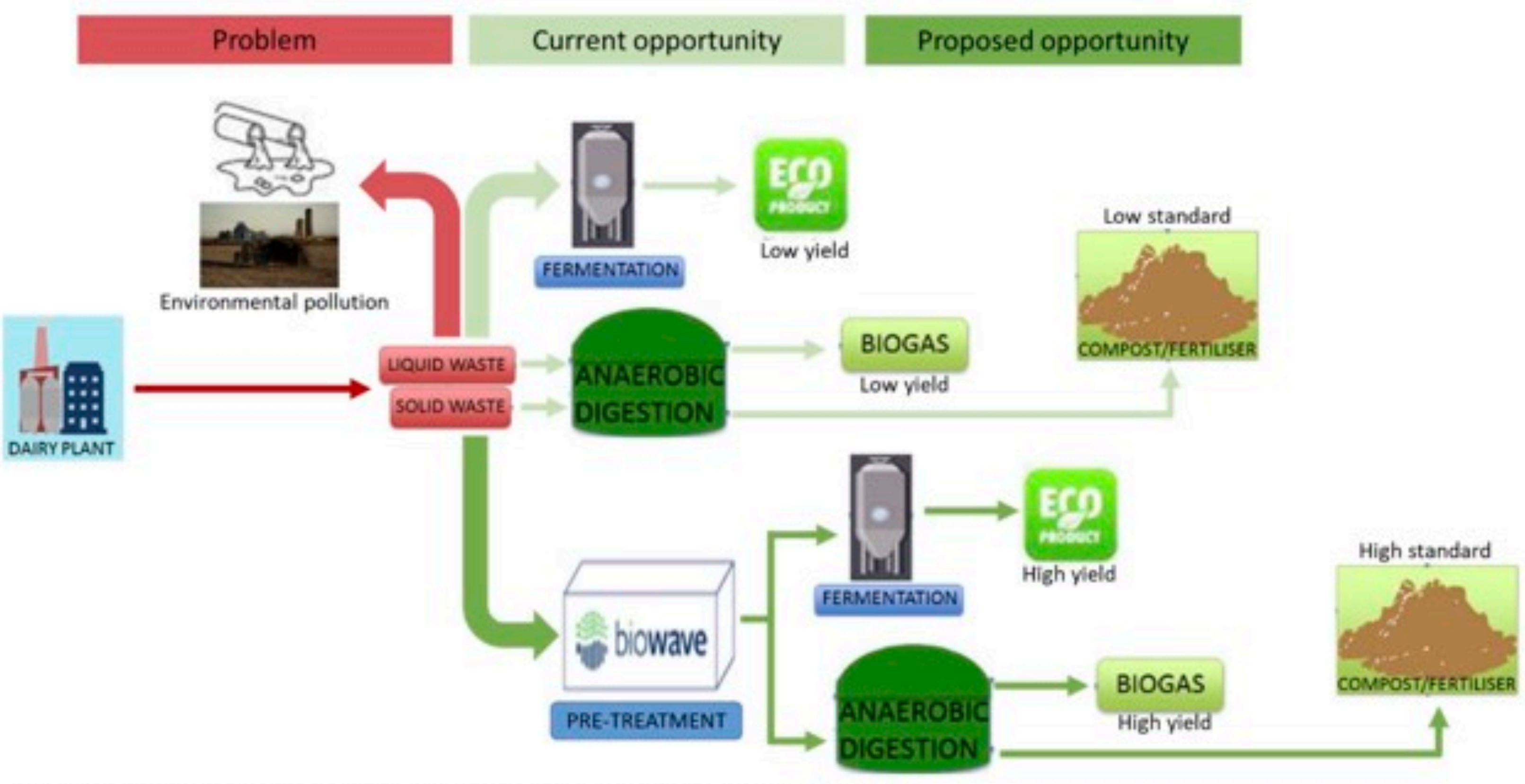

Fig 1 Future industry impact-Advancing dairy processing

Objective of Research

Evaluate the microwave pre-treatment methods to enhance digestibility of brown and DAF sludges through anaerobic digestion system.

Fig 2 Experimental Setup

Value provided to Industry

1)The value of the brown and DAF sludge can be unlocked using the combination of microwave pretreatment and anaerobic digestion

Microwave pretreatment unlocks the complexity of brown and DAF sludges by releasing soluble fermentative components.

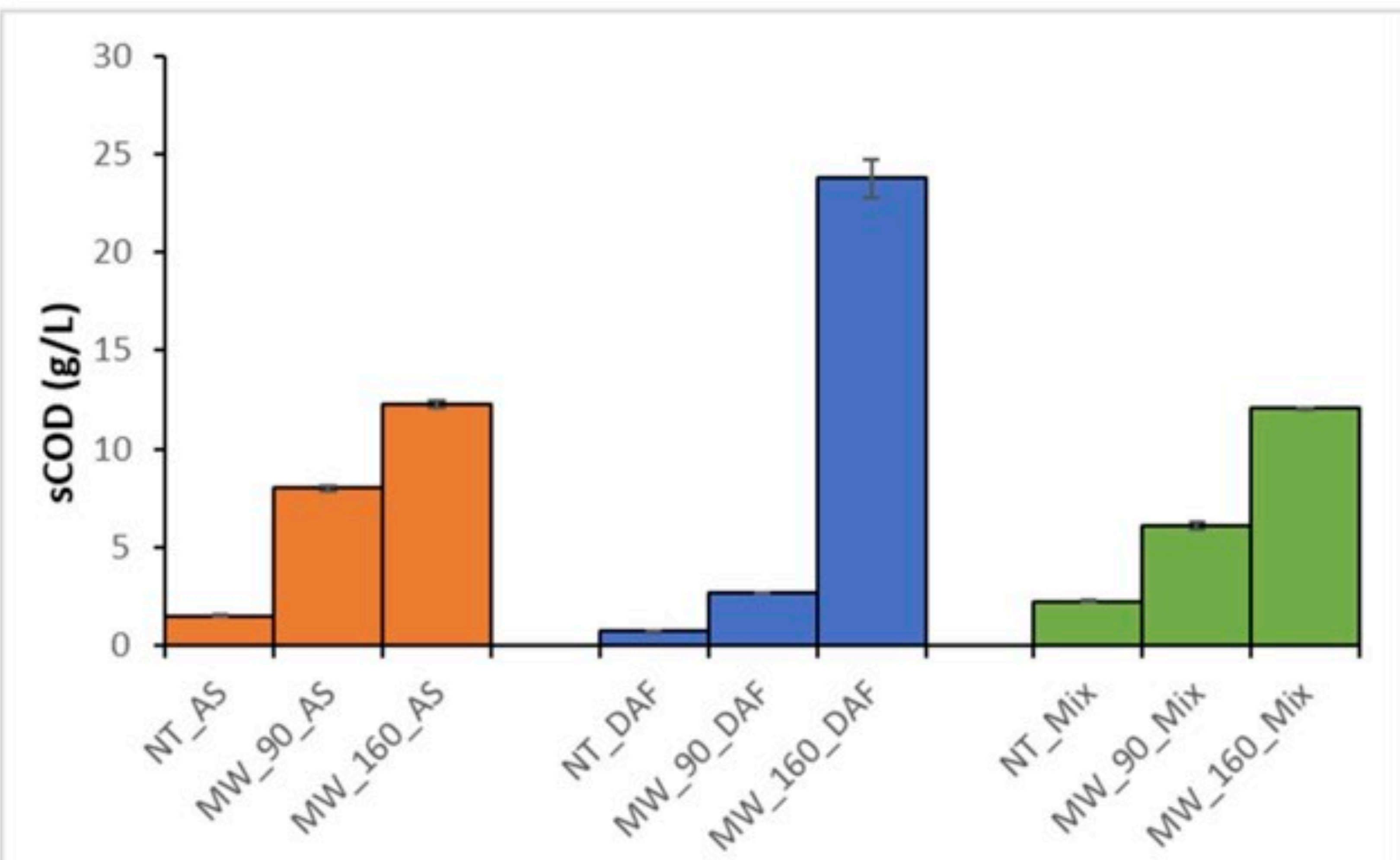

Fig 3 Soluble chemical oxygen demand (sCOD) before and after pretreatment. MW: Microwave; AS: Activated sludge; Mix: 70AS + 30% DAF (VS basis).

2) Higher and net positive energy recovery from microwave-pretreated brown and DAF sludges

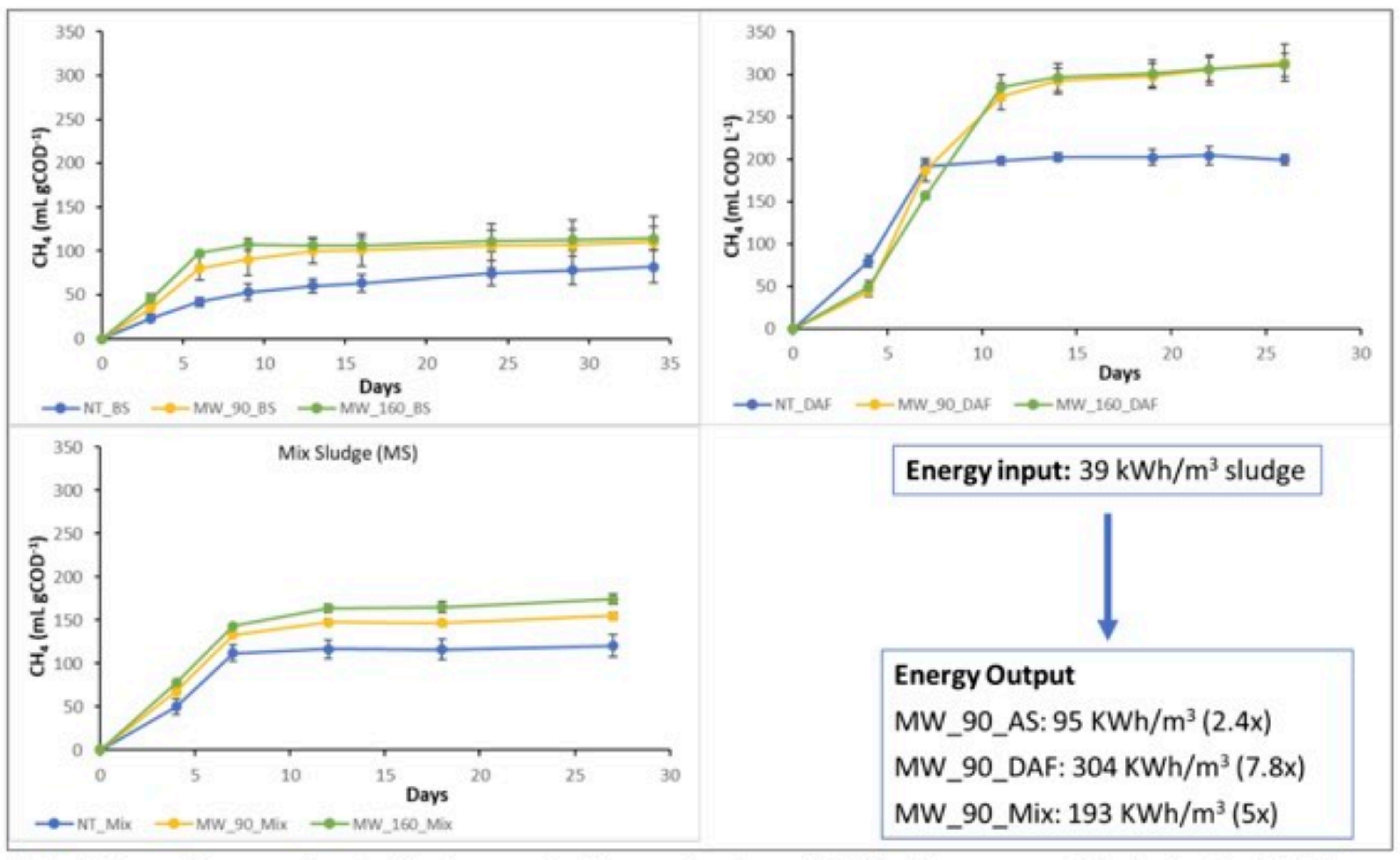

Fig 4 Biomethane potential before and after pretreatment. MW: Microwave; AS: Activated sludge; Mix: 70AS + 30% DAF (VS basis).

3) Reduction of sludge volumes by 70% - reduced costs.

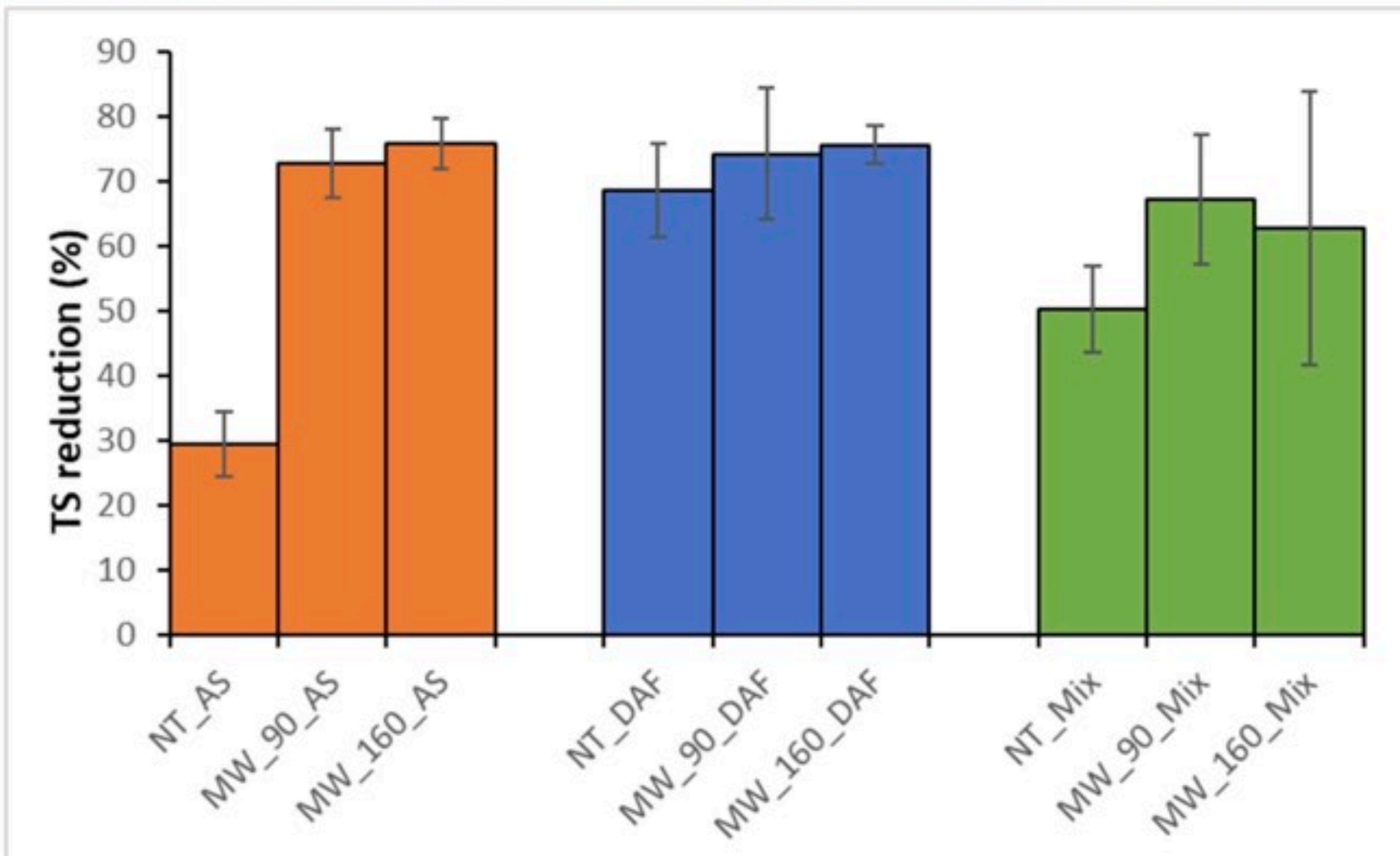

Fig 5 Total solid (TS) removal before and after the pretreatment. MW: Microwave; AS: Activated sludge; Mix: 70AS + 30% DAF (VS basis).

4) Reduced odour and carbon footprint of dairy wastewater treatment

***Table 3** Microwave (MW) and BMP efficiency of activated sludge (AS), DAF and mixed sludge.*

Substrates	sCOD efficiency (x)	TS reduction efficiency (x)	CH_4 production efficiency (%)
MW_90_AS	5.3	2.4	30
MW_160_AS	8.14	2.6	39
MW_90_DAF	4	1.1	57
MW_160_DAF	33	1.1	56
MW_90_ 70% AS + 30% DAF	2.7	1.3	29
MW_160_ 70% AS + 30% DAF	5.4	1.25	45

Future Industry Impact – Advancing Dairy Processing

- Transformed effluent streams from a burden into a valuable resource.
- Robust, future-proofed regulatory compliance.
- More sustainable milk processing.
- Feedstock supply into bioeconomy/nutrient value chains represents novel income streams for the industry.

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Co-digestion of DAF Sludge and Digestate: Influence of Hydrodynamic Cavitation Pretreatment

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Objectives

- Dissolved Air Flotation (DAF) sludge: Inhibits growth of microbes – difficult to process and valorise despite rich source of carbon.
- Anaerobic co-digestion overcomes mono-digestion limits and improves biodegradability.
- Digestate holds the potential for further degradation due to undigested organic matter and nutrients that support microbial growth.
- The study presents a method to improve the methane generation potential of DAF sludge by co-digesting with digestate and Hydrodynamic Cavitation (HC) pretreatment.

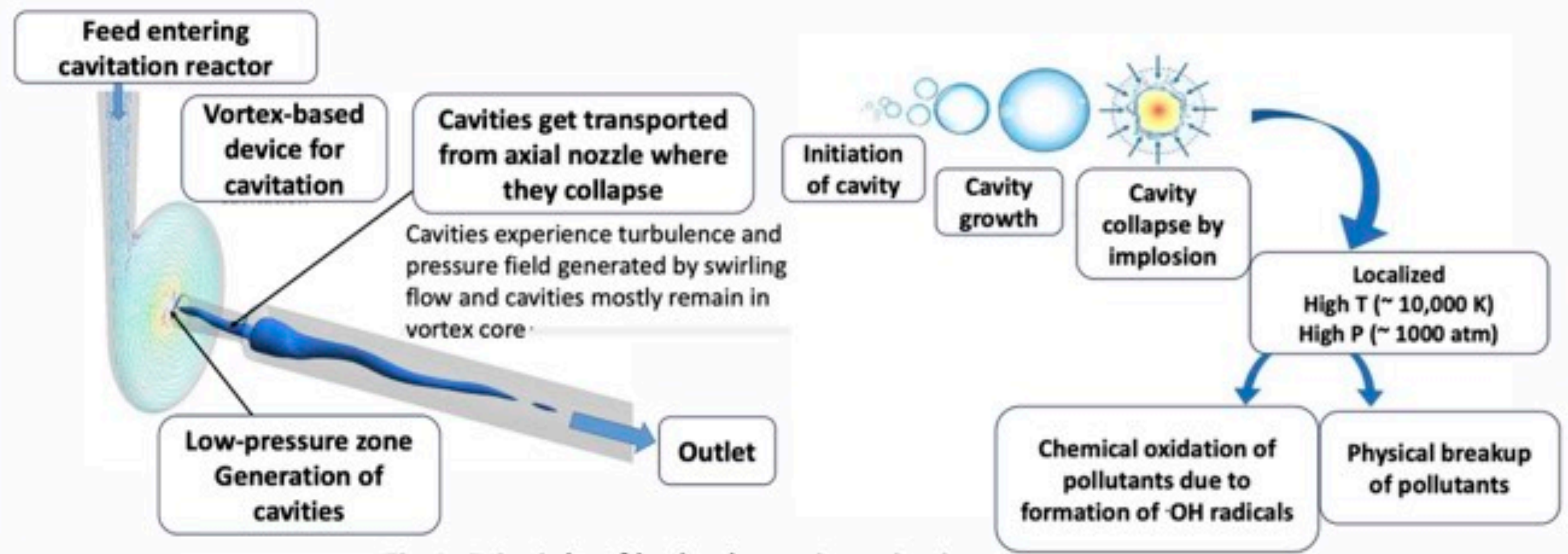
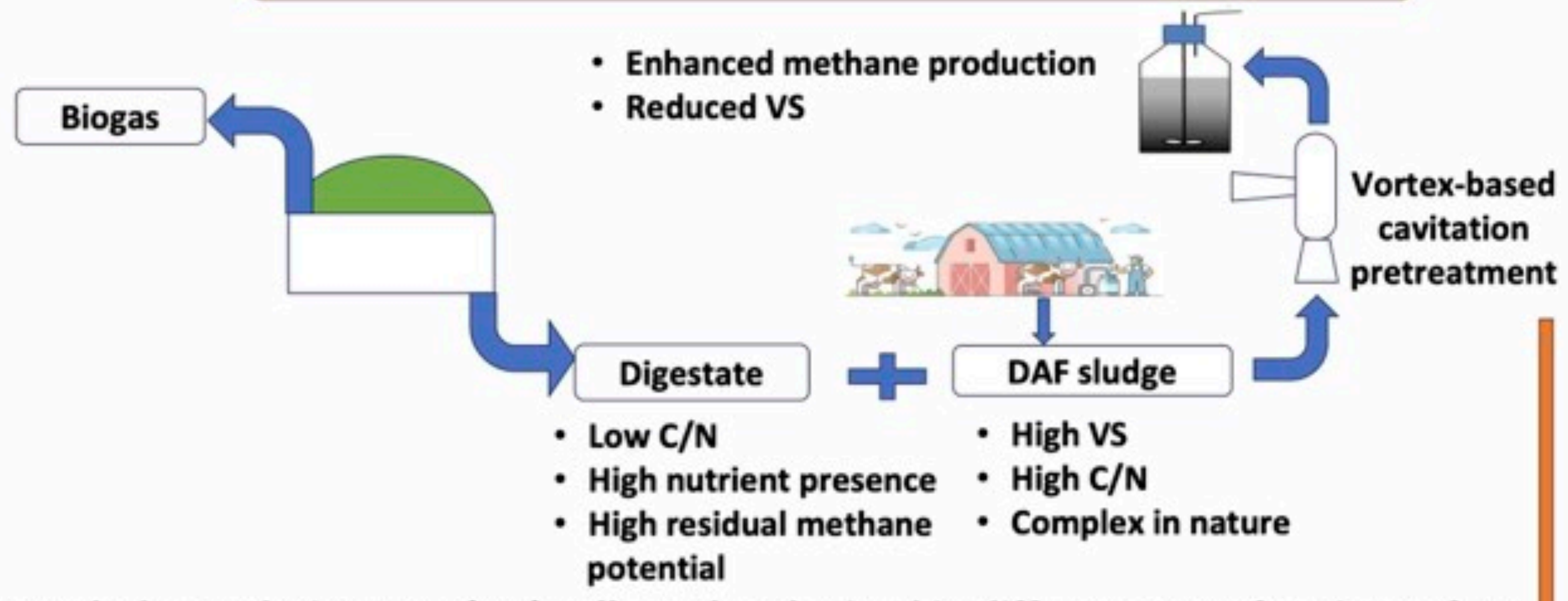


Fig 1: Principle of hydrodynamic cavitation

Experimental Section



- DAF sludge and Digestate (BD) collected and mixed in different mass fractions of VS.
- There are 15 BMP reactors available for each set of experiments.
- All the samples have been analysed in triplicate.

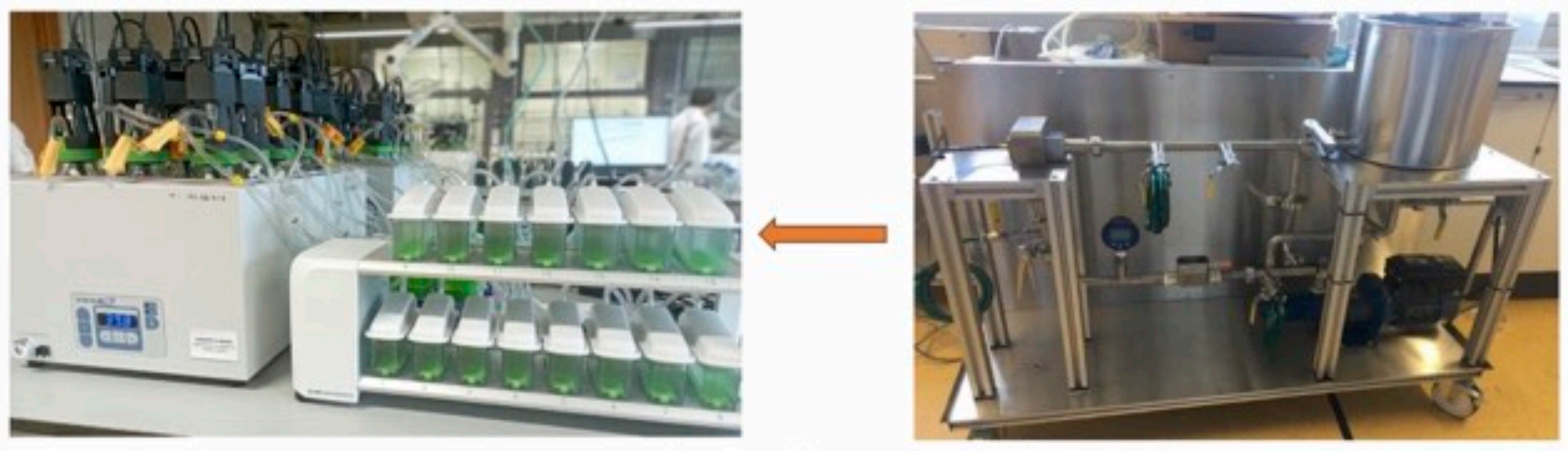


Fig 2: Experimental setup of BMP setup and HC pretreatment

Results and Discussion

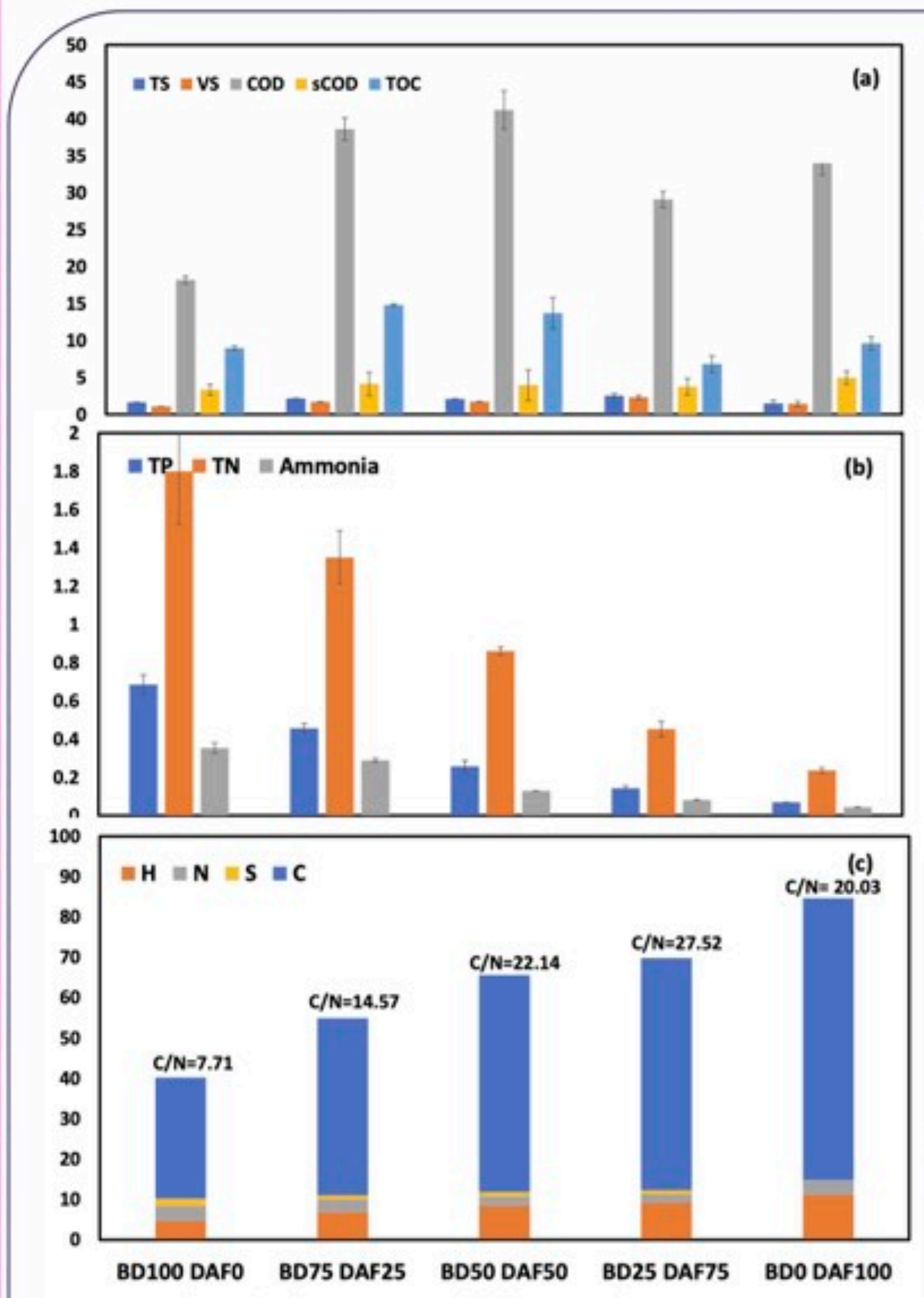


Fig 3a, b, c: The characterization of different samples

- Co-digestion of DAF with digestate increased solid content and organic matter in the samples.
- The presence of nitrogen components decreased with the increase of DAF sludge which might provide favourable conditions for further degradation and generation of methane.
- C/N ratio is increasing with the increase in DAF percentage.
- Synergetic effect showed maximum methane generation in the 50% VS fraction of DAF and digestate.
- Maximum methane generation of 683.67 mL/gm VS was achieved from BD50 DAF50 with a BMP conversion ratio of 89%.
- A second set of experiments was conducted with pretreatment HC in different passes of BD50 DAF50 sample.
- Significant methane production of 63.31% was achieved with 80 passes.
- HC pretreatment shows an effective method for enhancing residual methane production from digestate.

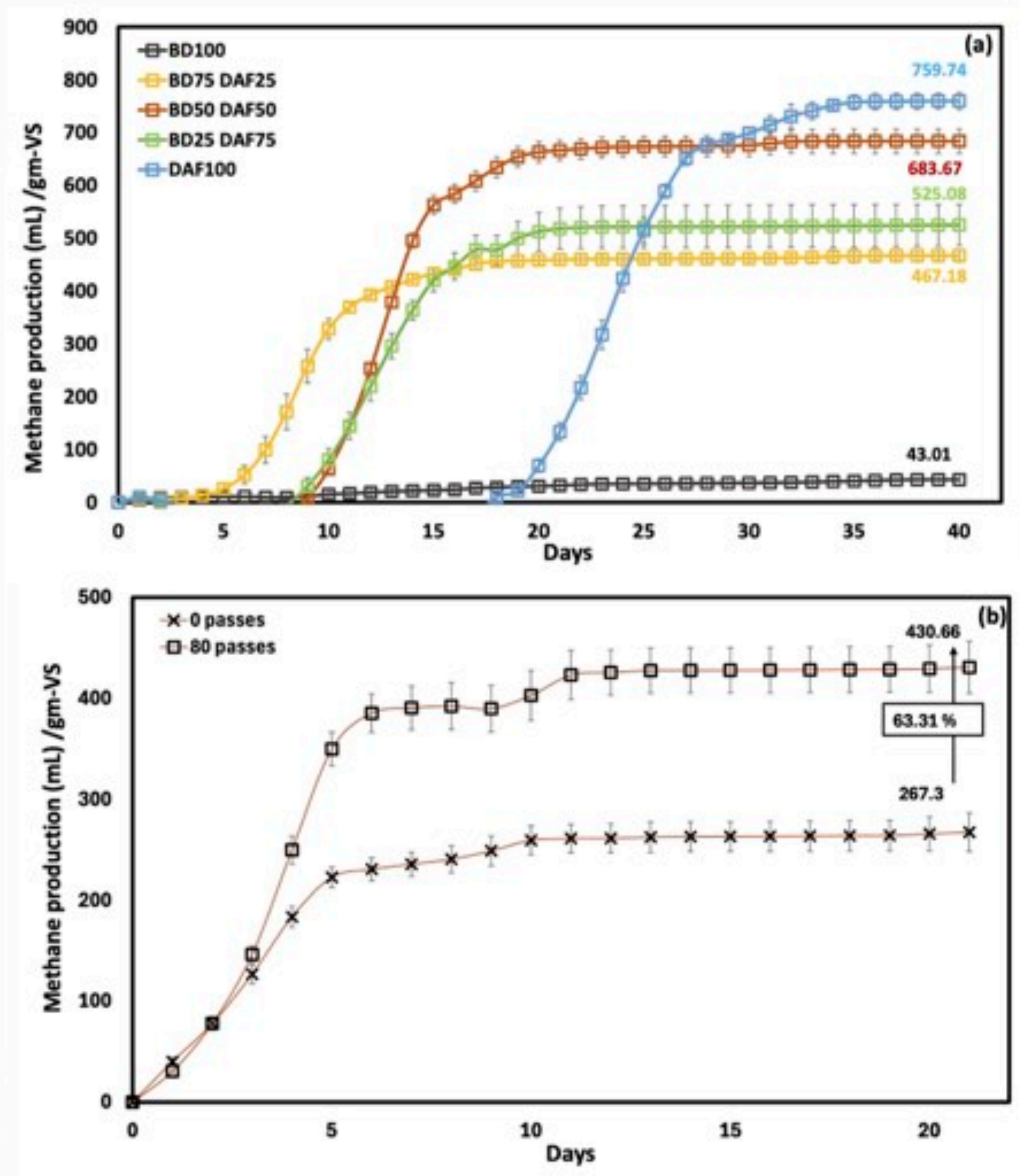


Fig 4a, and b: The methane generation of co-digestion samples and HC pretreated samples respectively

- The kinetics for the methane generation was fit using the modified Gompertz model.
- This kinetic model accurately predicted the methane production for all co-digestion experiments.
- Max. rate of generation (R_m) of 122.39 mL/g-VS and a lag phase of 9.83 d^{-1} were observed in the case of BD50 DAF50.

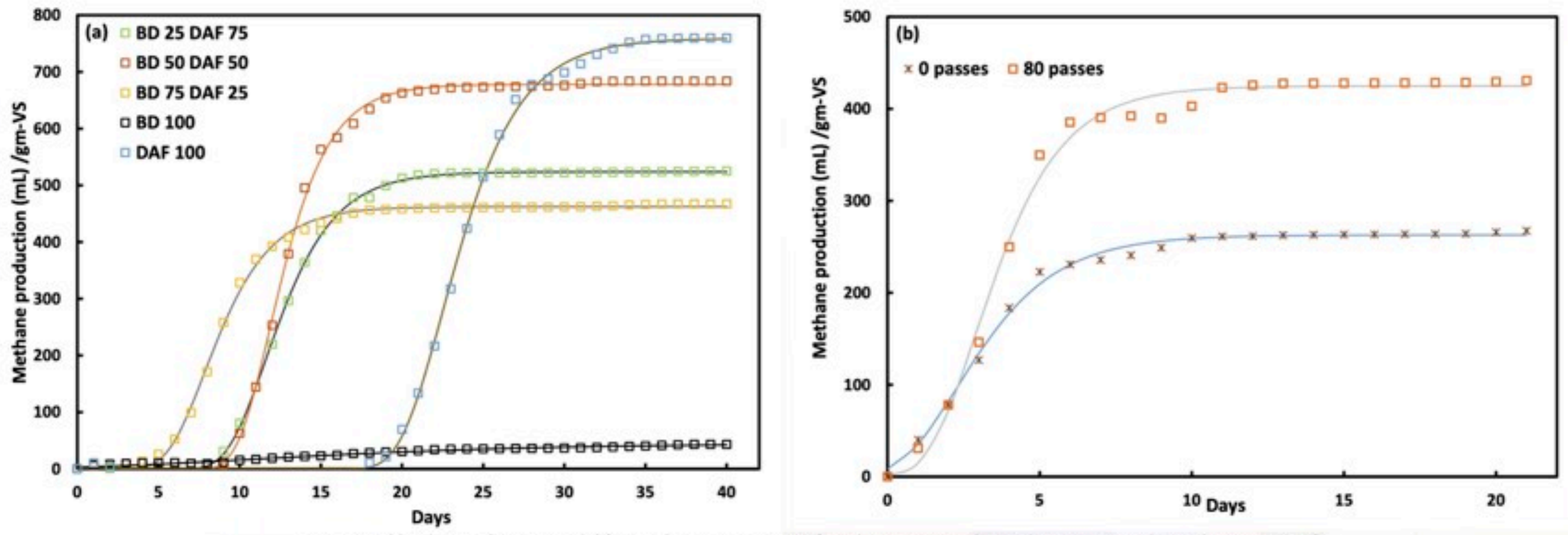


Fig 5a, and b: The MG kinetic model for methane generation of co-digestion samples and HC pretreated samples respectively

- Figure 5b shows the kinetic fitting of methane production for 0 and 80 passes with HC pretreatment.
- The results are well-fitted using a modified Gompertz kinetic model (with lower RMSE).
- A significant reduction in the lag phase was observed with HC pretreatment, while the biogas yield rate remained almost the same.

Conclusions

- In summary, co-digestion of carbon-rich DAF sludge with digestate effectively addresses the limitations of digestate management, improved C/N ratio, reduced complexity, and increased biodegradability.
- HC as a pretreatment method enhances substrate solubility, leading to increased methane generation.
- Integration of co-digestion and HC techniques offers a promising approach for optimizing DAF and digestate valorization and enhancing anaerobic digestion processes.

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DPTC DAIRY PROCESSING TECHNOLOGY CENTRE

DPTC SUSTAINABILITY RESEARCH

CIRCULAR DAIRY ECONOMY: HARNESSING OPPORTUNITIES FOR A SUSTAINABLE FUTURE

ASSESSING THE IMPACT OF DAIRY SLUDGE VALORISATION APPROACHES ON ODOUR MITIGATION

Joseph Niwagaba, DPTC RFA 2

Supervised by	Associate Prof Thomas P Curran

Background

Due to the removal of the milk quota regime in April 2015, the Irish dairy industry has seen continual fluctuations in milk production having increased from 5.7 billion litres in 2014 to 8.4 billion litres in 2023 (CSO, 2024). Dairy processing requires a significant hydraulic demand, with approximately 2.71 m^3 of water required to process 1 m^3 of milk (O'Connor, 2020). This results in large volumes of wastewater with potential to cause water, air and soil pollution.

The dairy processing industry generates 126,718 tonnes/year of dairy processing sludge (DPS), mainly Dissolved Air Flotation (DAF), and brown sludges. Most of the sludge goes to land spreading and a portion is going to anaerobic digestion (AD) without pretreatment (Ashekuzzaman et al., 2019).

Dairy processing plants have been identified as one of the sources of odour complaints in Ireland (EPA, 2023). Across all industry sectors, odour and noise complaints resulted in 22 cases and one circuit court case resulting in total fines of €137,750 and cost of €245,047 (EPA, 2023).

Objective of Research

In collaboration with industry and research partners in the Dairy Processing Technology Centre (DPTC), the impact of volarisation approaches of dairy processing sludge to recover nutrients, energy, water and odour mitigation as well as odour baseline studies at industry wastewater treatment plants have been investigated. The baseline odour monitoring at industry partners included identifying odour hot spots and is being followed by air dispersion modelling of odour in the atmosphere to assess odour impact downwind. The specific objectives of the research are:

Objective 1: To carry out odour baseline assessments at selected industry partner sites
Objective 2: Assess the impact of Hydrothermal Carbonisation (HTC) treatment of dairy processing sludge on odour emissions
Objective 3: Assess the impact of Hydrodynamic Cavitation (HC) and Anaerobic Digestion (AD) treatment of dairy processing sludge on odour emissions
Objective 4: Assess the impact of microwave, ultra-sonification and AD treatment of dairy processing sludge on odour emissions

Materials and Methods

Samples were collected using appropriate equipment as per sampling point requirements into Nalophan™ 10 litre odour bags using vacuum sampler as shown in Figure 1 and delivered for analysis within 24 hours from the time of sample collection.

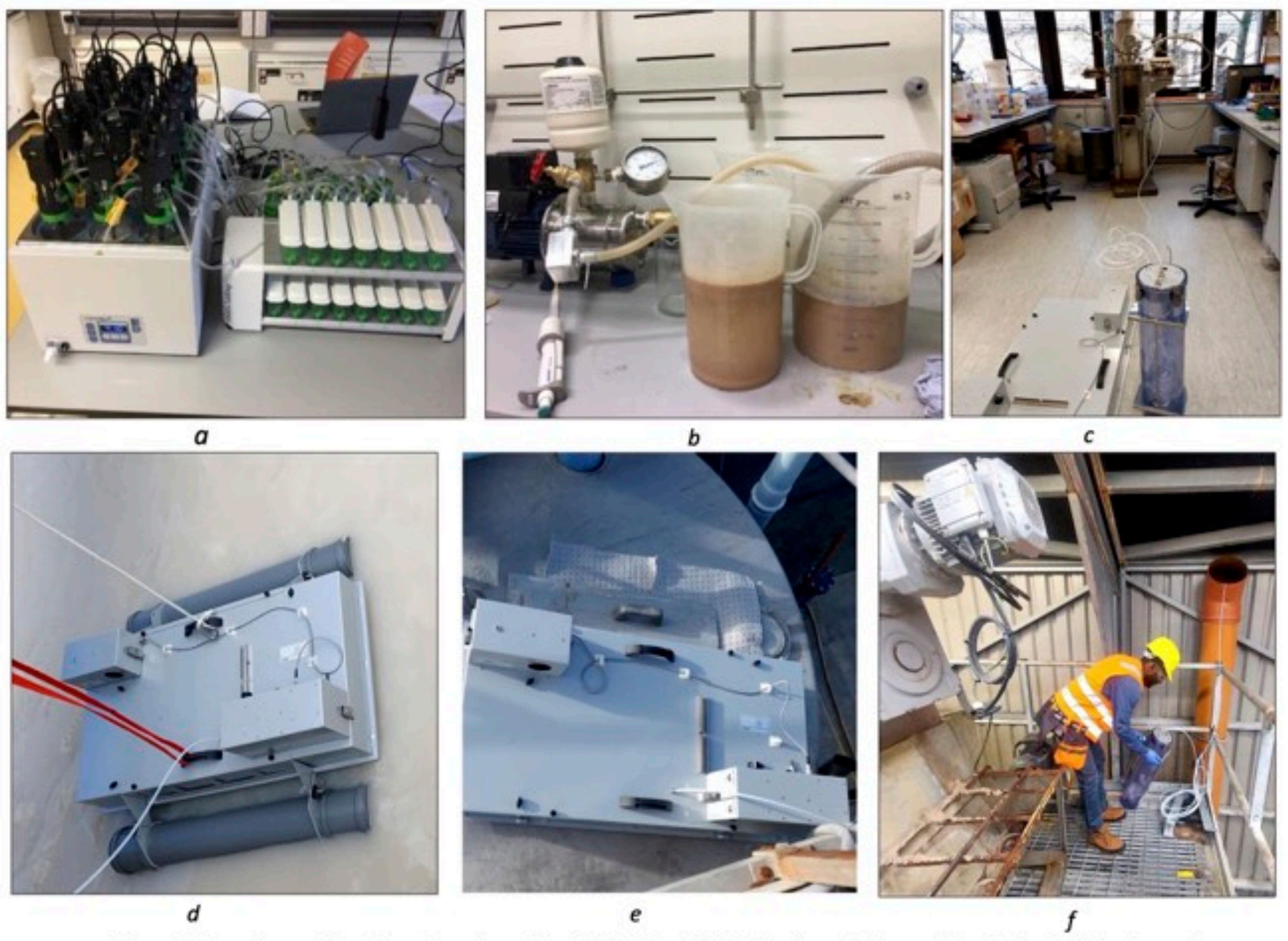

Figure 1: Sampling and treatment equipment (a-AD, b-HC, c-HTC, d-balance tank, e-sludge tank, f- sludge house)

Odour Analysis

After sampling, the olfactometer T08 (Olfasense) at UCD Odour Laboratory (Figure 2) was used to analyse the samples with a YES/NO option according to the European Standard for Dynamic Olfactometry EN13725.

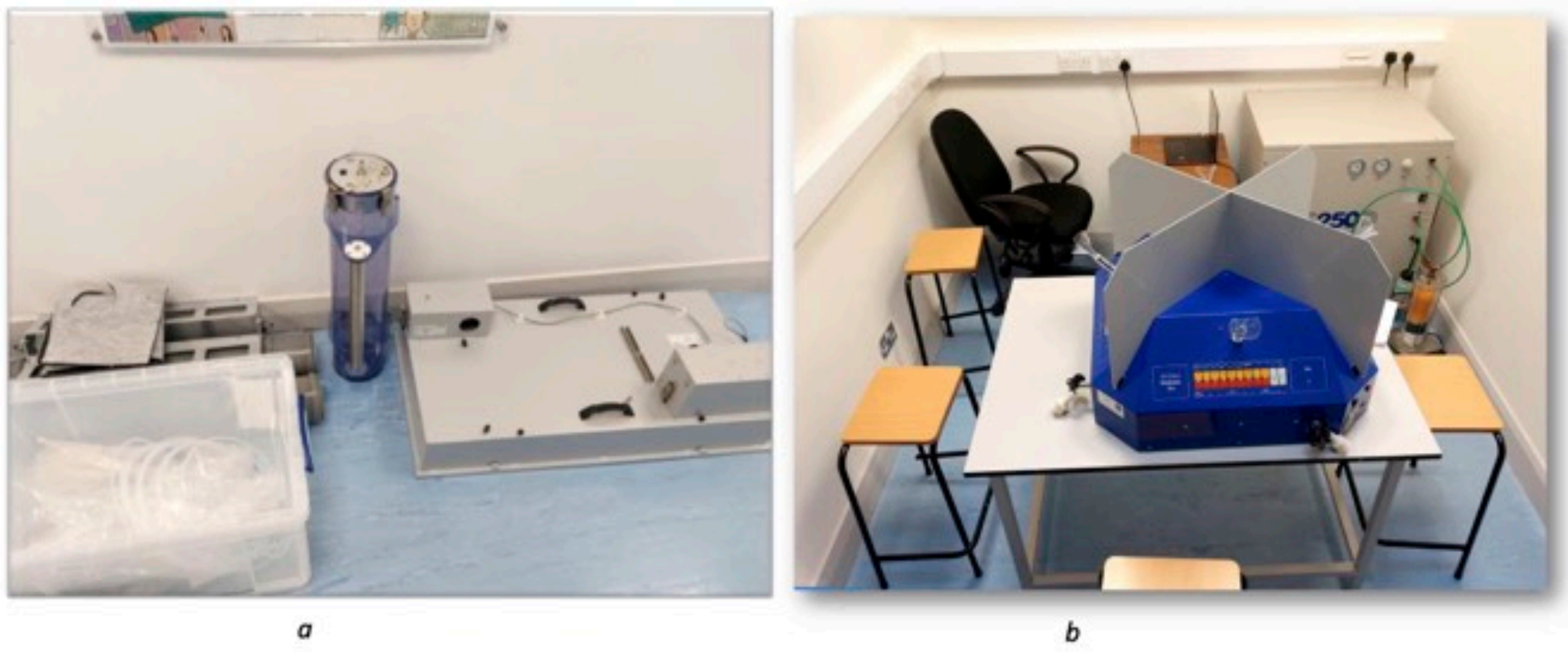

Figure 2: a- Sampling equipment, b- UCD odour laboratory

Value provided to Industry / Circular Economy / Sustainability Goals to-date

Improved on-site odour assessment and abatement which is crucial in EPA licence conditions.

The on-site operations affect odour emissions, therefore, will change with time.

Individual industry reports highlighting odour hot spots and their respective odour concentration have been produced.

Some sludge valorisation approaches such as hydrothermal carbonisation increased odour concentrations by over 40-fold, thus deployment of such approaches on industrial scale will require odour control measures.

Future Industry Impact – Advancing Dairy Processing

Assessed impact of dairy sludge valorisation approaches such as hydrothermal carbonisation, hydrodynamic cavitation, microwave, ultrasonication and anaerobic digestion on odour emissions in the dairy processing industry.

Odour baseline assessment reports of industry partner wastewater treatment plants indicating odour hot spots, odour emissions of the hot spots and atmospheric dispersion models showing the impact of terrain, land use and meteorological data on odour dispersion downwind.

Improved technical support on odour monitoring, mitigation recommendations and EPA compliance.

Conclusions

- Sludge valorisation approaches that are thermal in nature release more odours, hence such approaches require odour control measures.
- Balance tanks show the highest odour concentrations, followed by sludges and buffer tanks and the exhaust stacks amongst sampled hot spots.
- Odour concentration varies constantly depending on processes, operations and weather conditions.

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DPTC SUSTAINABILTITY RESEARCH

CIRCULAR DAIRY ECONOMY: HARNESSING OPPORTUNITIES FOR A SUSTAINABLE FUTURE

Upstream Recovery of Phosphate from Dairy Wastewater

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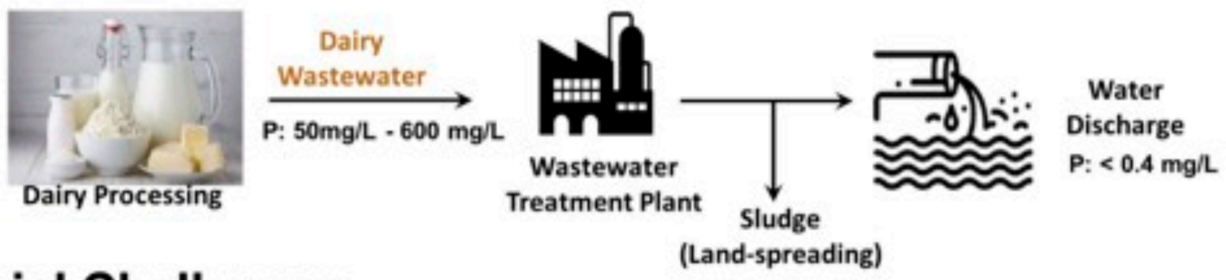
Background

- Dairy industries in EU27 generated 192.5 million tonne/annum dairy processing wastewater; Phosphate content 50- 600 mg/L
- Regulatory compliance with discharge levels; P < 0.4 mg/L is essential and leads to expensive infrastructure development

Conventional Dairy Wastewater Treatment

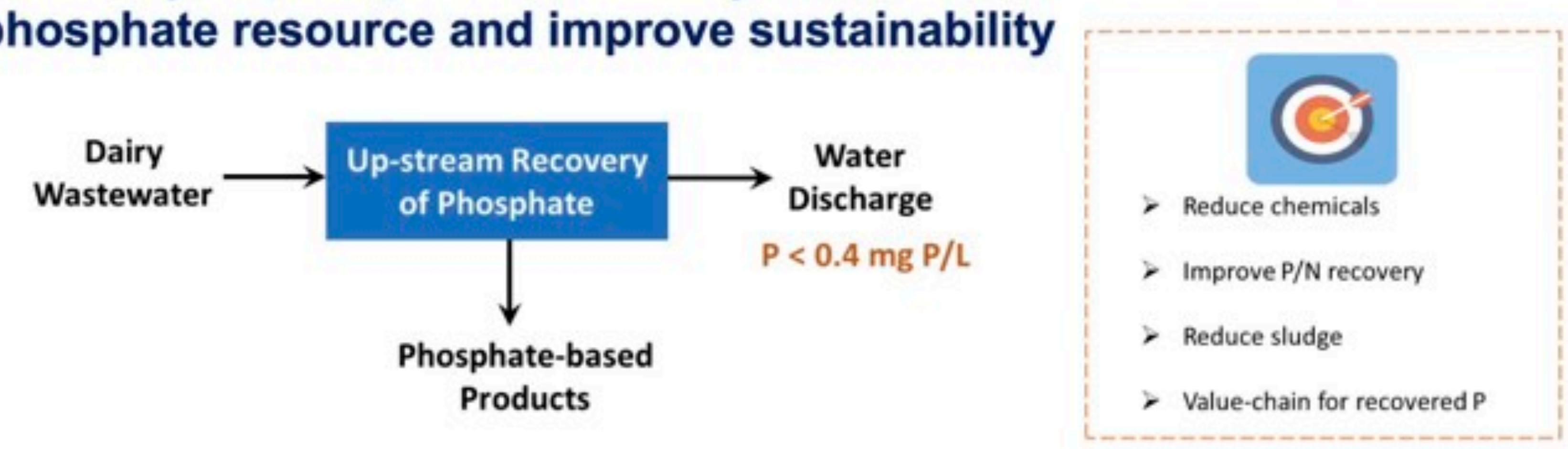


Industrial Challenges

- ➢ Excessive chemical utilisation
- ➢ Generation of high amount of chemical contaminated sludge
- ➢ High cost for management of dairy wastewater and sludge
- ➢ Development of robust technology for regulatory compliance

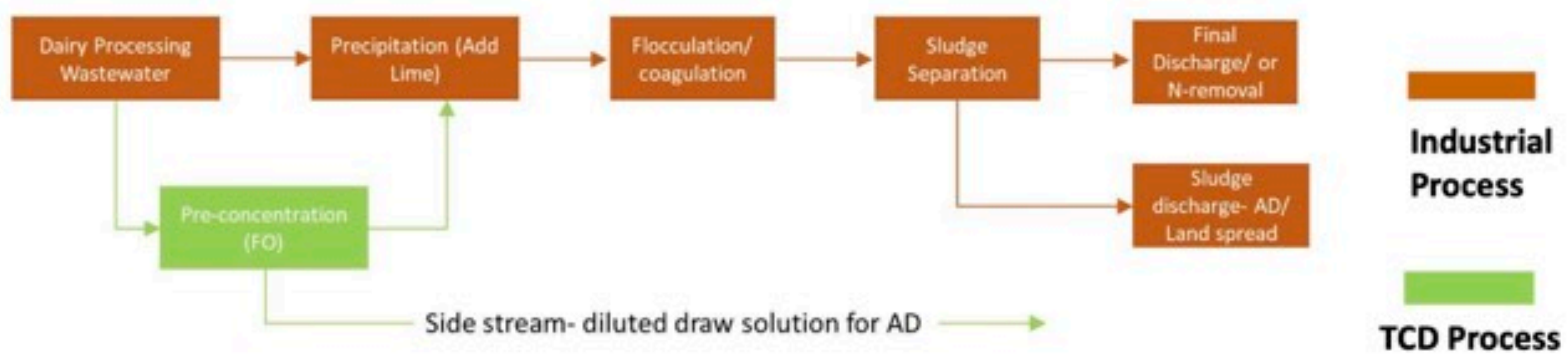
Objective of Research

Recovery of phosphate from dairy wastewater to create an alternate phosphate resource and improve sustainability



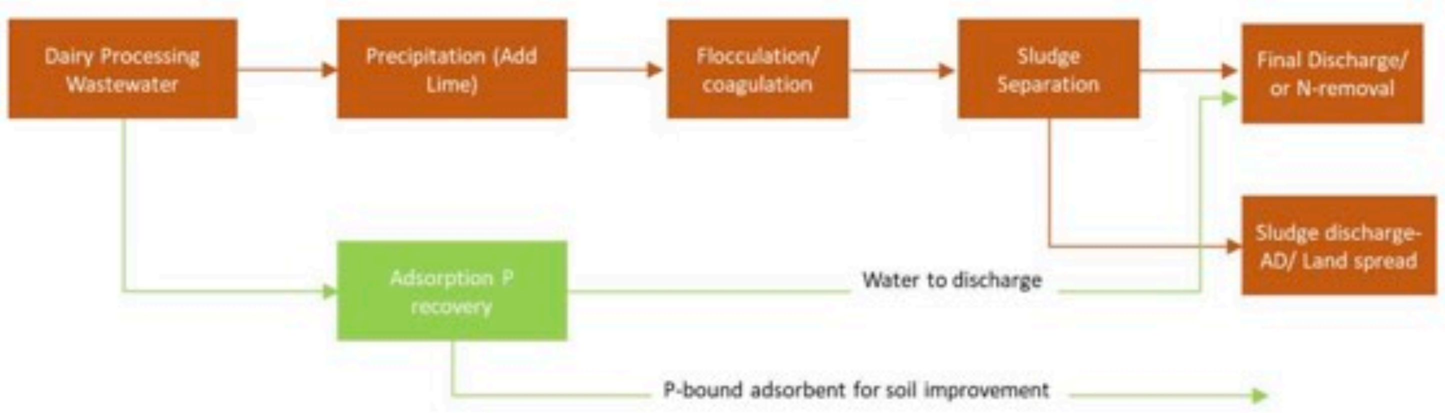
Value Provided to Industry

Forward Osmosis (FO)-integrated chemical precipitation



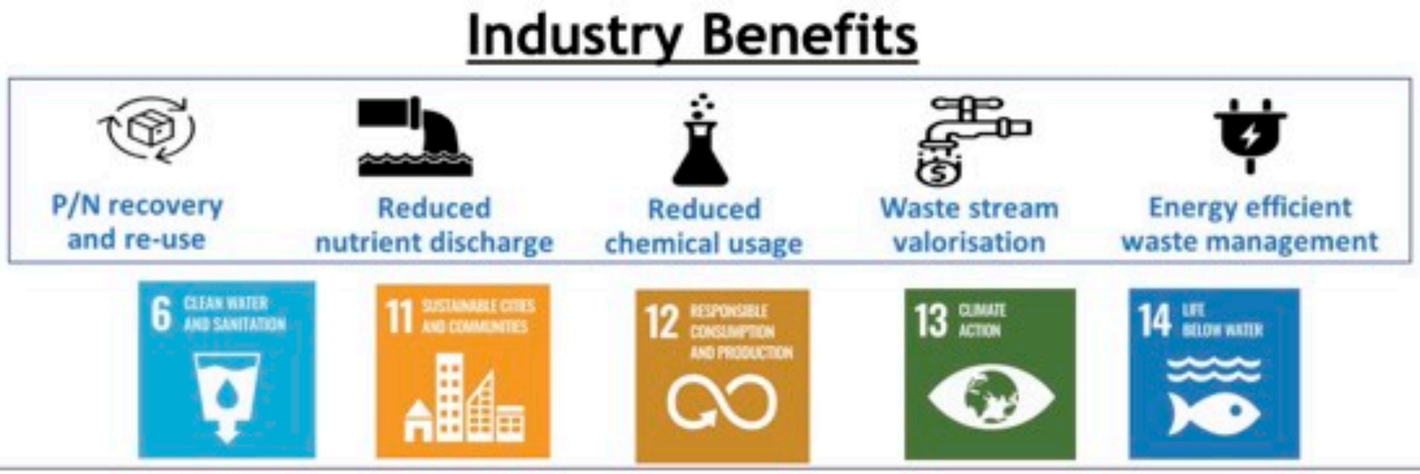
- Scalable- low energy pre-concentration
- **Chemical reduction**: 20%-60% ; **Desirable P level** achieved: <0.4 mg/L
- Phosphate recovered in the form of precipitate (calcium phosphate/ struvite)

Adsorption-based Phosphate removal process



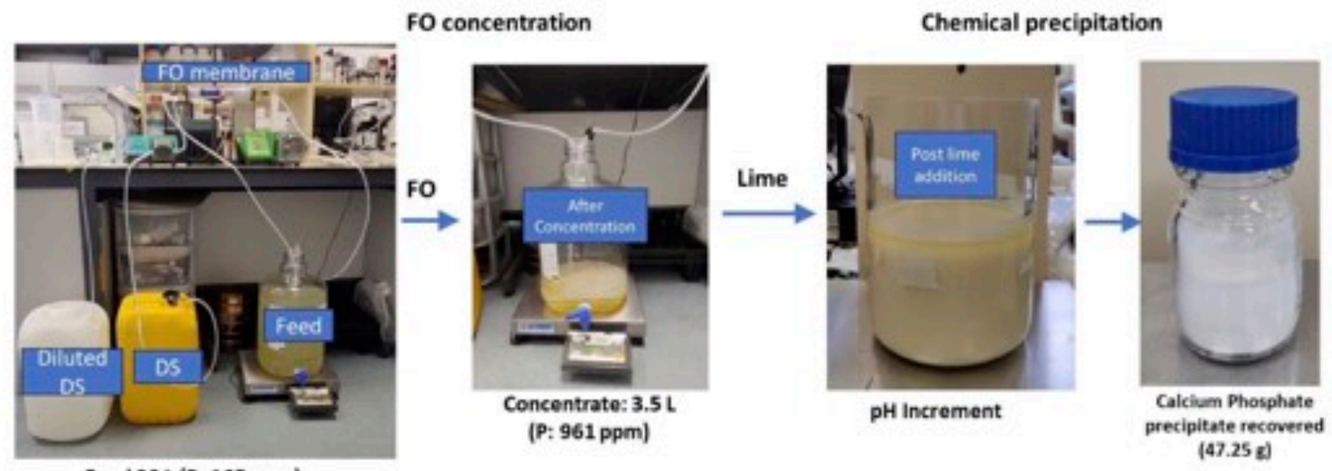
- Scalable- mineral-based adsorption for P removal
- **Desirable P level** achieved; **No chemical** requirement
- **P-Saturated adsorbents suitable for plant growth**

Industry Benefits



Research Insights

Forward osmosis-based concentration prior to chemical precipitation



FO module for industrial trial (13.2m²)

- Demonstrated scalability **to 20 L using** industrial samples
- Desirable P level achieved; **P Level < 0.4 ppm**
- Compared to control trial **33% reduction in lime usage**
- Phosphate precipitate: 47.25 gm (2.3 g/L)
- **Side-stream diluted** DS shows good potential **for biomethane production**

Absorption process for Phosphate removal

- Demonstrated **scalability at 50L**
- Feed sample: P 190ppm- 400 ppm
- **No chemical utilization**
- **No sludge generation**
- Saturated adsorbents used for plant growth improvement

Setup for 50 L scale-up

Research Outputs

- ➢ **Industrial case study with Irish dairy industry: 1**
  P removal with reduction in lime 40-60%, flocculant (80-85%) and sludge (50%) employing FO-integrated chemical precipitation
- ➢ **Invention Disclosure Form Registered: 1**
  RB01-1047-01: Development of a Novel Process for Dairy Wastewater Treatment

Future Industry Impact – Advancing Dairy Processing

- **Scalable technologies for robust compliance** with regulatory discharge levels
- **Significant reduction in chemical utilisation** in phosphate recovery with subsequent reduction in cost associated with chemicals and sludge management
- **Dairy wastewater as a potential resource of phosphate** which is a critical raw material and an essential nutrient in food-supply chain.
- **Improve sustainability of dairy industries** in Ireland through effective management of dairy processing wastewater by nutrient recovery and valorisation.

Potential Research Impact

The processing of **625 kilo tonne DWW/annum** from one Irish dairy plant (P concentration 230 mg P/L) using **FO-integrated chemical precipitation** process will generate

- Phosphate precipitate : ~ **750 tonne/annum**
- Revenue from Phosphate precipitate: ~ **€ 0.7 million** (@market price: ~ €930/tonne)

Extrapolating results to EU27 generating 192.5 million tonne DWW/annum

- Phosphate precipitate generation: ~ **0.2 million tonne/annum**
- Revenue from Phosphate precipitate: ~ **€ 214 million**

Conclusions

- ✓ Developed a scalable process for upstream recovery of phosphate well aligned with BAT and regulatory discharge level
- ✓ Demonstrated reduction in chemical utilization in P recovery adopting FO-based pre-concentration and stand-alone adsorption.
- ✓ Scale-up studies have been conducted for translation of lab-developed approaches to industrial scale

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InformBio

Integrated Framework for Mapping, Modelling and Monitoring Ireland's Bioeconomy

IDENTIFYING ENVIRONMENTALLY SUSTAINABLE AND SCALABLE FEEDSTOCKS FOR CIRCULAR BIOECONOMY

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Ollscoil na Gaillimhe University of Galway
Teagasc Agriculture and Food Development Authority
An Phríomh-Oifig Staidrimh Central Statistics Office
An Roinn Talmhaíochta, Bia agus Mara Department of Agriculture, Food and the Marine
CONTRACT Nº 2021R423

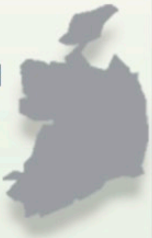
BACKGROUND

Planetary and ecological boundaries allow for a certain degree of environmental change before catastrophic consequences for the environment and humanity manifest. Monitoring and measuring global resources could help to ensure a sustainable bio-based resource exploitation

InformBio

MAPPING BIOMASS ARISINGS

A bio-based feedstocks (BBF) database that maps arisings and flows at national and county level in Ireland. Primary biomass, co-product and residue streams have been identified. The database gathers feedstock tonnage, hectarage and yield as well as the ratio of co-products and side streams generated from primary biomass



ENVIRONMENTAL RISK TOOL

The tool provides an early screening of environmental risks associated with increasing the demand for a specific feedstock. The methodology was informed by consequential life cycle thinking based on seven environmental aspects, followed by a structured approach that culminated in an overall environmental risk score for each of the seven environmental aspects based on two key factors: the Probability of risk occurrence and the Severity of consequences.

Probability	Severity of Consequences: Low	Medium	High
High	Medium Risk	High Risk	High Risk
Medium	Low Risk	Medium Risk	High Risk
Low	Low Risk	Low Risk	Medium Risk

	Score
High Risk	3
Medium Risk	2
Low Risk	1

Figure 1. Risk Table, used to estimate the environmental risk of feedstock for each environmental aspect based on Probability of occurrence and Severity of consequences. The scores assigned to each level of environmental risk are also presented.

Case study of an early-stage upstream environmental risk assessment for bioethanol production from alternative agricultural feedstocks in Ireland

1

BBF \ Availability & Composition	N&W (t)	S (t)	E&M (t)	DM	GCV	Ch.	TL	Constrained feedstock?
Barley straw	25,335.68	422,633.77	316,781.39	87.9	14.7	66.6	19.9	Yes
SMC	215,543.05	75,090.66	50,400.68	31.2	3.8	66.6	19.9	Yes
Wheat grain	7,404.38	149,109.83	91,059.56	87.0	15.8	84.5	1.1	No
BSG	5,495.63	91,674.56	68,713.85	91.0	19.7	90.8	5.4	Yes
Willow	1,356.48	674.10	5,536.89	93.2	19.5	52.6	27.0	No
Misconthus	117.70	4,547.00	1,262.30	92.4	18.5	53.0	23.4	No
APR	36.86	372.73	217.66	43.3	17.3	11.1	17.0	Yes

Table 1. Availability and key biochemical composition (in (%W/W) of the BBFs selected.

FROM THE BIOMASS DATABASE:

-Feedstocks suited to first generation (with a high concentration of carbohydrates) and second generation (lignocellulosic biomass) bioethanol production have been chosen.

-Wheat grain, straw from barley, spent mushroom compost (SMC), barley spent grain (BSG) from beer production, willow, *Miscanthus*, and apple pruning residues (APR).

-Biomass availability (tonnage) per region, dry matter (DM) content, gross calorific value (GCV), carbohydrates (Ch.) and total lignin, and constraints, i.e., availability is limited by environmental or economic factors.

RISK OF ENVIRONMENTAL IMPACT ASSESSMENT OF THE BBFs:

-Wheat grain had the greatest relative environmental risk associated with increasing the supply for bioethanol production.

-Increasing demand for wheat grain was associated with high environmental risks linked to production inputs and GHG emissions, air- and water-quality, indirect land use change and soil carbon loss (being a tillage crop)

-Apple pruning residues had the lowest risk.

-As a waste product, apple residues are unlikely to drive any additional production activities and are therefore associated with low environmental risk.

-Various by-products were associated with intermediate risks because their appropriation could lead to substitution effects that incur additional biomass production somewhere in the market.

2

BBF	Type	PFRI	Production GHG emissions	ILUC	Terrestrial C	Landscape Diversity	Air Quality	Water Quality	Overall Environmental Risk (/21)
Barley Straw	LVBP	2	2	2	2	2	2	2	14
SMC	LVBP	2	2	2	2	2	2	2	14
Wheat grain	DP	3	3	3	3	2	3	3	20
BSG	LVBP	2	2	2	2	2	2	2	14
Willow	DP	2	2	3	1	1	2	2	13
Misconthus	DP	2	2	3	1	1	2	2	13
APR	W	1	1	1	2	1	1	1	8

Table 2. Potential environmental risk associated with the selected BBFs.

CONCLUSIONS

The biomass availability database and the environmental risk matrix developed in the InformBio project can help to assess the biomass that an organisation could sustainably exploit as feedstocks for prospective bio-based value chains, respecting ecological and planetary boundaries. In the case study presented, high and low risk bio-based feedstocks were identified, illustrating the potential utility of these decision support tools.