WORLD BIOGAS ASSOCIATION

WHITE PAPER

Enhancing Biogas Performance:

The Role of Additives in Efficiency, Stability and Bioeconomic Growth

Introduction

Although the anaerobic digestion of organic material is a well-established process, it depends on complex sequential biochemical reactions of hydrolysis, acidogenesis, acetogenesis and methanogenesis, which can be optimised by introducing a range of additives to the core biobased ingredients. These additives can have a variety of effects, from improving the stability of the process, optimising the quality and quantity of the biomethane generated, to influencing the quality of the digestate and its end-use applications.

This paper provides an overview of the main categories of these additives, acting as a starting point so that plant operators can investigate them further and consider using them in their own facilities. Additionally, we will also provide insights from a few case studies of facilities that have pioneered the use of additives.

Historically, a broad range of additives have been utilised, including chemicals, microorganisms, enzymes and biochar. Microorganisms can alter the biochemistry that occurs within the digester, thus helping to catalyse hydrolysis or to stabilise the methanogenic process, and/or to impact the overall AD process from another perspective. Chemicals, primarily inorganic, can enhance the electrochemistry and acidity/alkalinity balance of the overall process whilst also optimising its sulphur and nitrogen derivative chemistry. Biochar, on the other hand, can affect the overall potential nutritional value of the digestate output. Enzymes facilitate new reactions within the digester, either altering the balance of outputs or potentially generating an alternative array of new outcomes.

Whilst these additives are not a universal solution in terms of enhancing rate and total biogas, and corresponding biomethane generation, when they are integrated into robust, focused operational strategies, they can unlock significant long-term environmental and economic improvements.

Authors: Aishwarya Moses, Daniel Lee, James McGreer, Maxime Briche, Hugo Roume
Reviewers: Karina Navarro, Kavya Koonampilli, Thibaut Raharofalimanana
Acknowledgements: Lesaffre, Deep Carbon Africa, Renewable Gas Forum Ireland (RGFI), 4T2 Sensors, RAFT Energy, Alps Ecoscience

1 Microorganisms

1.1 The Central Role of Micro-organisms in the AD Unit

Microorganisms in the anaerobic digester play a crucial role in the anaerobic digestion process. In the anaerobic environment, they are responsible for the decomposition of organic matter (fibres, proteins, lipids) into simpler molecules, ultimately transformed into methane by methanogenic archaea. The populations of micro-organisms present in the AD unit depend on and adapt to the environment: physico-chemical parameters (e.g. anaerobiosis, pH, temperature, contaminants), the nature of the feedstock, and interactions with other micro-organisms are all factors affecting their balance, which is crucial for maintaining a stable and efficient anaerobic digestion process.

1.2 Adding Micro-organisms to Catalyse Hydrolysis

Shaping the biology in the AD unit can help improve the efficiency of biogas biology in the digestion of the organic matter or could help fix problems due to inefficient digestion.

Like for enzymatic solutions, the enzymatic profile of micro-organisms can be key in the choice of microbial solutions, as it will determine which complex compound their action will be directed to and consequently which feedstock it will help to digest. It is particularly important when recalcitrant organic materials such as lignocellulosic materials are incorporated into the AD diet. Enhancing hydrolysis of this complex organic matter, such as cellulose, hemicellulose, and lignin could increase the access to readily biodegradable substrates for the subsequent stages of anaerobic digestion, leading to improved methane yields. Microbial solutions could be agile solutions due to the large enzymatic repertoire of microorganisms and their ability to adapt their production to the exact nature of the feedstock. In addition, unlike proteins such as enzymes that can be rapidly inactivated or degraded, micro-organisms can maintain extended metabolic activity under the physico-chemical conditions of the AD unit and self-maintain and regenerate as long as necessary nutrients and environmental conditions are provided.

Several strategies can be put in place: either microorganisms with a large metabolic versatility can be used, or a cocktail of several microorganisms selected based on complementary actions may be proposed, offering agile solutions for anaerobic digestibility enhancement.

1.3 Adding Microorganisms to Stabilise the Methanogenic Processes

Many solutions on the market are proposed primarily for their ability to participate in the hydrolysis step, as they synthesise hydrolytic enzymes to support the breakdown of complex organic matter. However, too much emphasis on hydrolysis might favour the accumulation of hydrogen or volatile fatty acids, which can inhibit methanogenesis if not properly managed, or lead to a slower growth rate of other microorganisms involved in the overall process. Live Yeast has been proposed as a regulator of volatile acids production and accumulation while promoting acetogenesis, which could help stabilise and enhance the anaerobic digestion process. Another microbial solution is claimed to help limit the accumulation of volatile fatty acids, helping to increase the "charge" of the biogas unit.

Microorganisms can also engage in syntrophic interactions, in which different species cooperate to carry out specific metabolic steps. Syntrophic relationships with methanogenic archaea can accelerate the degradation of organic matter and increase methane yield, while contributing to the stability of the methanisation process in a more energy-efficient manner.

Some microbial solutions aim to inhibit the growth of certain 'harmful' bacteria in methane production, such as Sulphate-Reducing Bacteria (SRB), which compete with methane-producing archaea for organic substrates and hydrogen, reducing the resources available to methane-producing archaea and negatively impacting methane production.

Microbial solutions show tremendous potential in shaping the biology of the AD unit to increase methane yield and process stability, and to address challenges such as feedstock variability and the demand for flexible production. While scientific knowledge and commercial offerings are growing, consistency in quality will be key for their adoption in the industry.

CASE STUDY

Applying Safgasus™ Live yeast to improve anaerobic digestion process efficiency and stability in Northern Ireland.

Objective

Safgasus™ Live yeast is a patent-pending microbial solution containing a highly concentrated strain of *Saccharomyces cerevisiae* (CNCM I-6169, Lesaffre proprietary strain) and developed for the biogas industry. This study aimed at demonstrating the efficacy of Safgasus™ Live yeast at improving the efficiency and stability of anaerobic digestion process on a commercial biogas unit located in Northern Ireland.

Material and methods

The trial was conducted at a 500 kW_e combined heat and power anaerobic digestion facility commissioned in 2016. The plant operated a two-stage CSTR system comprising a primary and a secondary digester, each 2,714 m^3, operating in series. The system's hydraulic retention time was around 47 days.

The facility processes approximately 49 t fresh material per day of agricultural feedstocks, with the following contributions (fresh material): grass silage (35%), pig slurry (31%), lactose permeate (16%), chicken litter (8%), FYM (3%), vegetables (3%), maize silage (2%), and potato starch (2%). These feedstocks corresponded to an average daily organic dry matter of 8.45 oDM/d. Feedstock quality parameters were determined, including standard theoretical biogas potential measures.

Safgasus™ Live yeast was incorporated daily directly with the incoming feedstocks stream over a 13-week supplementation period (Dec. 2025-April. 2026) corresponding to approximately two hydraulic retention cycles.

Energy output

Parameter	Control	Safgasus™ Live yeast	Difference	Percentage difference
Electric generation (average daily) (MWh)	945	1035	90	9.5%
Average output capacity (kW)	433	474	41	9.5%
Total CHP running efficiency	86.5%	94.7%	8.2%	9.5%

Energy output increased by 9.5%.

BMP conversion efficiency

Parameter	Control	Safgasus™ Live yeast	Difference	Percentage difference
Expected daily theoretical generation from BMP evaluations (kWh)	9556	9545	-11	-0.1%
Daily electric generation (kWh)	10381	11369	988	9.5%
BMP conversion efficiency	109%	119%	10.5%	9.6%

BMP conversion efficiency increased by 9.6%.

System Stability & Health Indicators

Routine digester health parameters remained within a generally acceptable operating range during the supplementation phase, with no indication from the recorded pH, FOS/TAC, ammonium-N or VFA measures that yeast addition caused process upset. On the contrary, the available monitoring data are consistent with the interpretation that the biological process remained robust while higher output was being achieved.

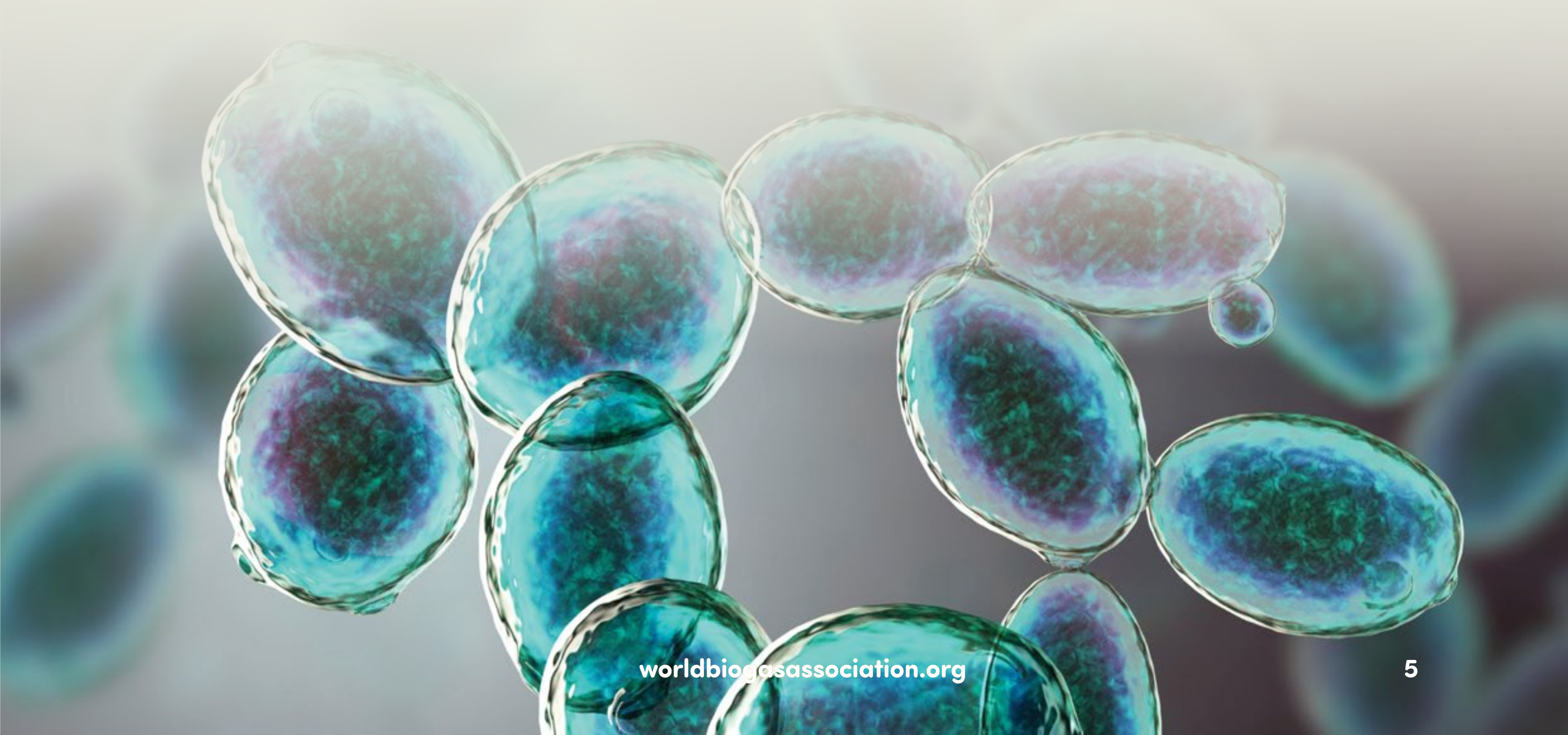
Economic Impact

Parameter	Control	Safgasus™ Live yeast	Difference	Percentage difference
Daily electricity revenue (£)	4256	4661	405	9.5%
Daily feeding costs (£)	829	882.1	53.1	6.4%
Feeding cost of production(£/MWh)	79.9	77.6	-2.3	-2.9%

Despite feeding costs increased by £53.1 per day, feeding costs of production declined by £2.3. The intervention yielded a net financial gain of £304.9 per day, corresponding to a return on investment ratio of 6.5:1.

Conclusion

Supplementation with Safgasus™ Live Yeast demonstrated a 9.5% enhancement in energy output together with a 9.6% biomethane conversion efficiency while maintaining optimal digester stability and health indicators. This improvement reflects both increased biological efficiency and enhanced process stability within the anaerobic digestion system. The microbial intervention proved to be a cost-effective solution, delivering a return on investment of 6.5:1.



2 Chemical additives

Chemical additives have a significant role throughout the anaerobic digestion processes including alkaline, acidic and oxidative pretreatments, which initiate lignocellulose deconstruction, floc-disintegration and oxidation of recalcitrant fractions, improved methanogenic conversion through the introduction of conductive materials (including biochar, graphene and magnetite {Fe_3O_4}) and overall reactor system stability through buffering of volatile fatty acids (VFA) accumulation and trace element supplementation (including Fe, Co and Ni which support enzyme pathways).

2.1 Improved methanogenic conversion

The addition of conductive materials, including biochar, graphene, and magnetite nanoparticles, significantly enhances anaerobic digestion by promoting Direct Interspecies Electron Transfer (DIET) between the syntrophic bacteria and methanogenic archaea. In many systems, DIET reduces reliance on diffusional hydrogen transfer and can accelerate methanogenic conversion, particularly under stressed or high-loading conditions. Biochar (Section 5) is particularly versatile herein as it coincidentally enhances conductivity, generates pH buffering, and facilitates microbial surface attachment.

2.2 Reactor System Stability

Buffering systems and trace-element supplementation are amongst the most practical additive strategies because they address instability directly. Ash, Biochar, and Phosphate buffers can stabilise pH in reactors exposed to VFA accumulation, while trace elements such as Fe, Co, and Ni support enzymatic pathways required for methanogenesis. However, trace-element dosing windows are narrow, site-specific, and excessive supplementation may create toxicity or precipitation problems.

To optimise anaerobic digestion, specific additive solutions need to address the precise bottlenecks or failure modes that dominate the plant's optimal operation. anaerobic digestion, conductive materials best address electron-transfer bottlenecks and buffers or trace elements resolve pH and micronutrient instability.

Furthermore, the formation and accumulation of sulphur hydrides throughout the anaerobic digestion process and in the emergent biogas can be curtailed using copper-based additives, which employ a dual mechanism: limiting the activity of sulphate-reducing bacteria and precipitating dissolved sulphide as copper salts. (SARGO, 2026)

CASE STUDY

Food Waste AD: bio-organic catalyst (BOC) dosing

Multi-Year Case Study: BOC dosing improves digester stability and produces 16% higher biogas yield.
(Nolan, Hughes, Thorn, Thorn, & O'Flaherty, 2023)

A UK food waste anaerobic digestion facility running mesophilic CSTR digestion adopted bio-organic catalyst (BOC) dosing in February 2020. The site operates 3.2 MW CHP and had almost two years of baseline operational data before dosing started.

Benefits at this site

- Statistically significant methane yield uplift in every post-BOC year block
- Up to 16% peak methane yield uplift versus baseline
- Improved pH stability, supporting more predictable operation
- Optimum BOC dose range identified at 1.1-1.2 L/tVS
- Estimated annual net benefit of approximately £245,000

Digester type	CSTR
Operating mode	Mesophilic
Annual throughput	Approx. 9,000 tVS/year
Primary feedstock	Food waste
Energy outputs	CHP
BOC adoption	February 2020 Dataset 2,933 daily records, 2018- 2026

Up to 16% peak methane yield uplift	**£25.85/tVS** average net gain	**~ £245k/year** estimated annual net benefit	**~ £1.5m** estimated six-year value

Results

Every post-BOC operating year showed higher mean energy yield per tonne of volatile solids than the pre-BOC baseline of 2,051 kWh/tVS. The strongest year block reached 2,377 kWh/tVS, equivalent to an uplift of approximately 16%. Welch two-sample t-tests confirmed statistical significance ($p < 0.05$) in all post-BOC year blocks.

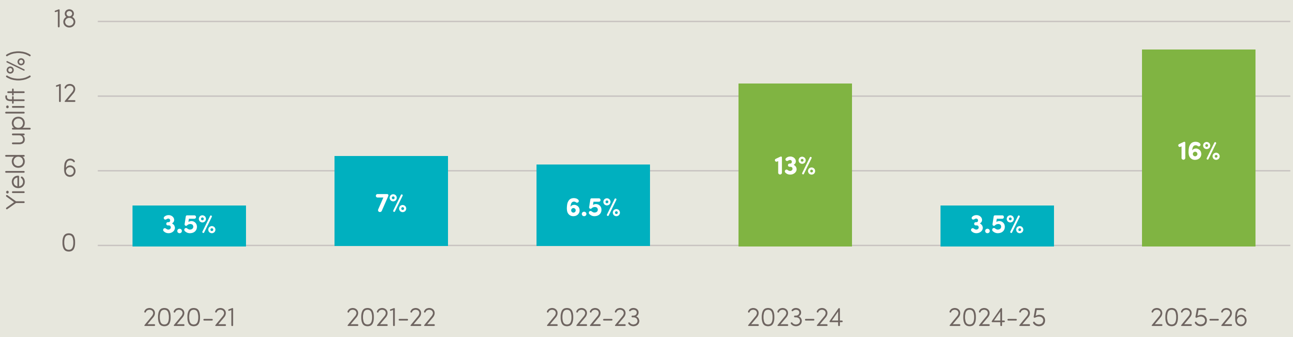


Figure 3. Observed methane yield uplift by operating year block after BOC adoption.

Performance and stability

A lag-corrected regression model was used to account for the biological memory of anaerobic digestion, including a 10-day BOC influence window, 2-day yield memory, OLR and HRT. The model explained approximately 24% of daily methane output variability, a material result for one controllable input in a commercial food waste AD system. Post-BOC operation also showed tighter pH control. Pre-BOC mean pH was 7.49 with a standard deviation of 0.47. Post-BOC mean pH generally remained in the 7.8-8.2 range, with lower variability. This reduces the risk of VFA accumulation and supports more predictable gas output.

How does BOC work?

BOC acts as both a surfactant and an enzyme catalyst enhancer. The surfactant effect improves contact between substrate and microbial community; the catalytic effect supports more complete volatile solids conversion. Together, these mechanisms increase accessible substrate and improve the biological response.

Dose optimisation

The observed optimum operating range was 1.1-1.2 L BOC per tonne of VS fed. Below this range, yield was measurably lower; above it, incremental benefit flattened. Because the response is lagged, each dose level should be held for at least 72 hours before assessment and reviewed using a 3-day moving average.

Financial impact

<table>
<tr><td>Gross revenue uplift</td><td>£43.25/tVS</td><td rowspan="5">At this site, the estimated six-year cumulative net benefit is £1.5 million.</td></tr>
<tr><td>BOC cost</td><td>£17.40/tVS</td></tr>
<tr><td>Net financial gain</td><td>£25.85/tVS</td></tr>
<tr><td>Return on dosing cost</td><td>~148%</td></tr>
<tr><td>Estimated annual net benefit</td><td>~£245,000/year</td></tr>
</table>

3 Biochar

Biochar, known as biological charcoal, is a stable, carbon-rich (>70%), solid, black material synthesised through pyrolysis (300°–700°C), a process that involves thermal decomposition under limited oxygen conditions. It possesses several distinctive physicochemical properties, including high porosity, large specific surface area, favourable electrical conductivity, which enables microorganisms to exchange electrons directly rather than relying on slower intermediates such as hydrogen (H_2) or formate ($HCOO^-$), and substantial cation-exchange capacity. Its properties are strongly influenced by the characteristics of the feedstock, production pathways such as gasification, pyrolysis, hydrothermal carbonisation (HTC) and liquefaction (HTL), and operational parameters such as heating rate, peak temperature, residence time, and carrier gas composition.

Biochar is primarily produced from a variety of residual streams, including agricultural and forestry residues, food waste, and sewage sludge. This strategic approach toward targeted residual feedstocks offers sustainable solutions for waste management, mitigates GHG emissions and improves resource utilisation. Apart from its application to soil for regenerative agriculture, soil health, landscape restoration, and biodiversity preservation, biochar is also recognised by the UNFCCC and the EU's Carbon Removal Certification Framework (CRCF) as a carbon dioxide removal (CDR) agent.

3.1 Effects of biochar use

In recent years, a growing body of research has investigated the incorporation of biochar as a process stimulant in anaerobic digestion, with numerous studies reporting its potential to enhance methane yields and overall system performance, leaving less residual carbon to decompose later. Owing to its capacity to buffer pH, enrich functional microbial consortia, mitigate the effects of inhibitory compounds, and facilitate direct interspecies electron transfer (DIET), biochar stabilises reactor conditions and mitigates common inhibitors, demonstrating a significant potential as an effective additive for enhancing anaerobic digestion processes.

These effects collectively lead to higher methane yields and more resilient AD performance. For instance, biochar's specific surface area varies widely from less than 10 m^2/g in low-temperature chars to 300–400 m^2/g in typical non-activated biochar and can exceed 1,000 m^2/g when chemically or physically activated. The well-developed pore structure of biochar is a primary contributor to its large specific surface area (Figure 1). Biochar's porous structure and large surface area provide physical niches for microbial colonisation (Figure 2). This supports the growth of syntrophic bacteria and methanogenic archaea, improving metabolic cooperation. Methanogens are slow-growing and sensitive; biochar provides them with a protected microhabitat, thereby increasing their abundance and activity.

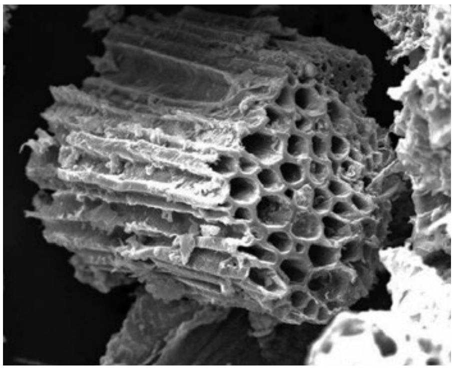


Figure 1. Image of porous structure of biochar, obtained from Scanning Electron Microscope (SEM) Source: (GĄSIOR & TIC, 2017)

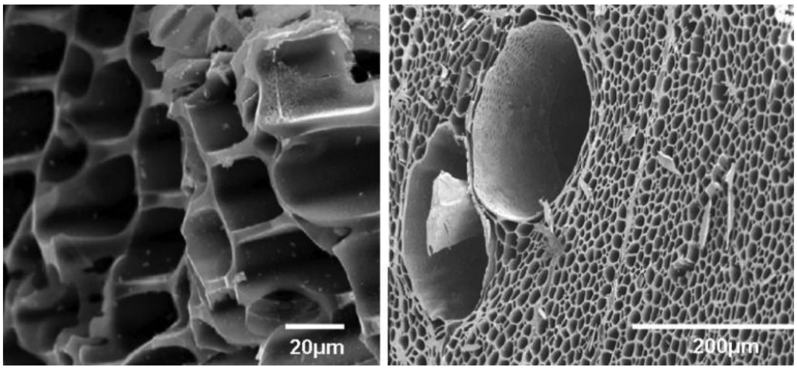


Figure 2. The porous structure of biochar invites microbial colonisation Source: (Thies & Matthias, 2009)

3.2 How biochar influences the FOS/TAC ratio

FOS/TAC is a key parameter for assessing substrate degradability during anaerobic digestion. It translates to the ratio of Volatile Fatty Acids (FOS) to Total Alkalinity/Buffer Capacity (TAC), providing a highly accurate snapshot of the equilibrium within a digester. Biochar acts on both components of the FOS/TAC[1] ratio simultaneously. This dual mechanism makes it a particularly effective process stabiliser, especially under conditions of organic overloading, inhibitory feedstock composition, or reactor stress. The porous surface structure and oxygenated functional groups of biochar, particularly those produced at lower pyrolysis temperatures (300–450°C), provide active adsorption sites for volatile fatty acids. This physical sequestration of volatile fatty acids (VFAs) reduces their free concentration in the liquid phase, alleviating acid stress on methanogenic communities.

Biochar's inherently alkaline nature, with pH typically ranging from 8.5 to 10, depending on feedstock and pyrolysis temperature, directly contributes to the digester's total alkalinity. This increase in alkalinity raises the bicarbonate buffering capacity of the system, enabling it to absorb greater acid loads without a destabilising pH drop. By simultaneously lowering FOS through adsorption and biodegradation acceleration, and raising TAC through alkalinity contribution, biochar effectively shifts the FOS/TAC ratio toward the stable operational range. This is reflected in the improved process metrics consistently reported in biochar-augmented AD systems: shorter lag phases, more stable daily methane production profiles, reduced variability between reactor replicates, and higher cumulative methane yields, particularly under conditions of organic overloading where unamended systems fail or underperform.

It is important to note that this stabilising effect is dosage dependent. Moderate biochar dosages of 5–10 g/L have been identified as optimal for VFA mitigation and methanogenic enhancement. Excessive dosages above 10–15 g/L have been associated with propionic acid accumulation, which is itself inhibitory to methanogens and can paradoxically destabilise the FOS/TAC ratio rather than improve it. (Jang, Choi, & Kan, 2018) (Luo, Lü, Shao, & He, 2015) (Shi, et al., 2022)

[1] FOS/TAC: FOS (*Flüchtige Organische Säuren*) measures Volatile Fatty Acids (VFA), while TAC (*Total Anorganisches Carbonat*) measures the total inorganic carbon buffer capacity.

CASE STUDY

Waste management and biogas optimisation using ActiCH4R.Ammonia and ActiCH4R.Biogas

RAFT Energy

This multi-phase project focuses on optimising agricultural waste valorisation and tackling regional nutrient pollution, specifically targeting poultry and abattoir waste streams.

Description	Multiple commercial-scale anaerobic digesters across independent trial sites
Location	United Kingdom (featuring applications relevant to the Wye Valley agricultural region)
Feedstocks used	Poultry litter, agricultural manure, and high-protein abattoir waste
Plant size/capacity	Commercial agricultural and industrial scale
Biogas application	Combined Heat and Power (CHP) generation and Biomethane Injection
Results	Increase in methane yield along with targeted CHP efficiency gains

The series of projects utilises a comprehensive approach to waste management and biogas optimisation using ActiCH4R.Ammonia and ActiCH4R.Biogas, RAFT Energy's proprietary biochar-based products.

The process begins directly at the source by treating poultry farm sheds. During the six-week cycles, while birds were housed during their growth phase, the ActiCH4R.Ammonia application achieved a 99% reduction in ammonia compared to untreated sheds. This dramatically improves bird health and creates a highly stable, pre-treated poultry waste product. When introduced to anaerobic digestion, this stabilised waste allows plant operators to process higher concentrations of poultry manure without experiencing biological upset.

Further optimisation occurs within the digester using the ActiCH4R.Biogas additive, which provides an ideal microbial habitat to boost digestion efficiency into biomethane.

In an AD plant with 25% poultry waste, this integration increased methane yields enough to drive CHP engine efficiency from the mid-80% range to the high 90% range. Plant operators also successfully reduced their ferric chloride dosing by 25%.

The technology's biological resilience was further proven during an abattoir waste trial. Despite a mid-cycle change in feedstock, adding ActiCH4R.Biogas delivered an increase in methane yield. The digester experienced zero foaming issues, and post-cycle analysis showed no residual biogas was left in the final digestate.

Ultimately, the ActiCH4R platform offers a highly scalable solution to pressing environmental challenges in sensitive areas like the Wye Valley. By preventing nutrient runoff and waterway pollution, boosting renewable energy yields, and producing a safer, higher-quality solid digestate, the technology transforms agricultural liabilities into high-performing assets.

4 Enzymes

Enzymes are specialised proteins (and occasionally RNA molecules) that act as biological catalysts, accelerating essential biochemical reactions by lowering the activation energy required, thereby enabling reactions that would otherwise occur very slowly under normal environmental conditions. They have a uniquely shaped region called an active site. Only a perfectly matching substrate molecule can bind there, making each enzyme highly specific to a particular reaction. For example, cellulase enzymes degrade cellulose, while lipases degrade fats and oils.

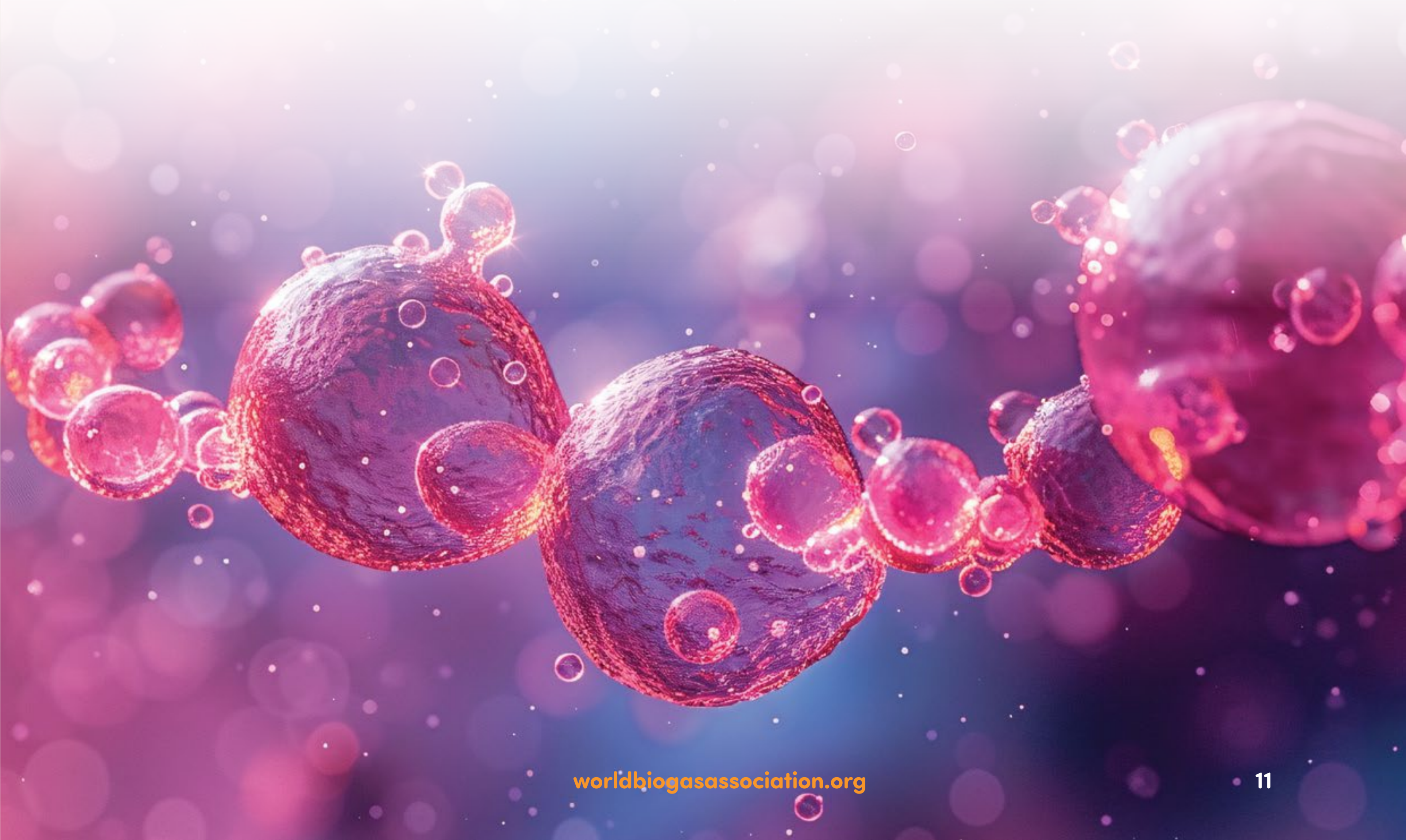
Enzymes are essential in all biological systems because they regulate metabolism and biochemical transformations. In anaerobic digestion, microorganisms produce extracellular and intracellular enzymes that decompose complex organic matter into smaller molecules.

Their activity depends on several environmental factors, including:

- Temperature
- pH
- Moisture content
- Availability of feedstock
- Presence of inhibitors
- Retention time

Which makes them very sensitive to their environment and work best under specific temperature and pH conditions. Extremes can denature them, destroying their shape and rendering them useless.

Although enzymes participate in all stages of AD, their role is especially significant during hydrolysis, the first stage. During this phase, often considered the bottleneck of AD, especially when treating lignocellulosic biomass, complex organic polymers such as carbohydrates, proteins, and lipids are broken down into soluble monomers that microorganisms can then absorb.

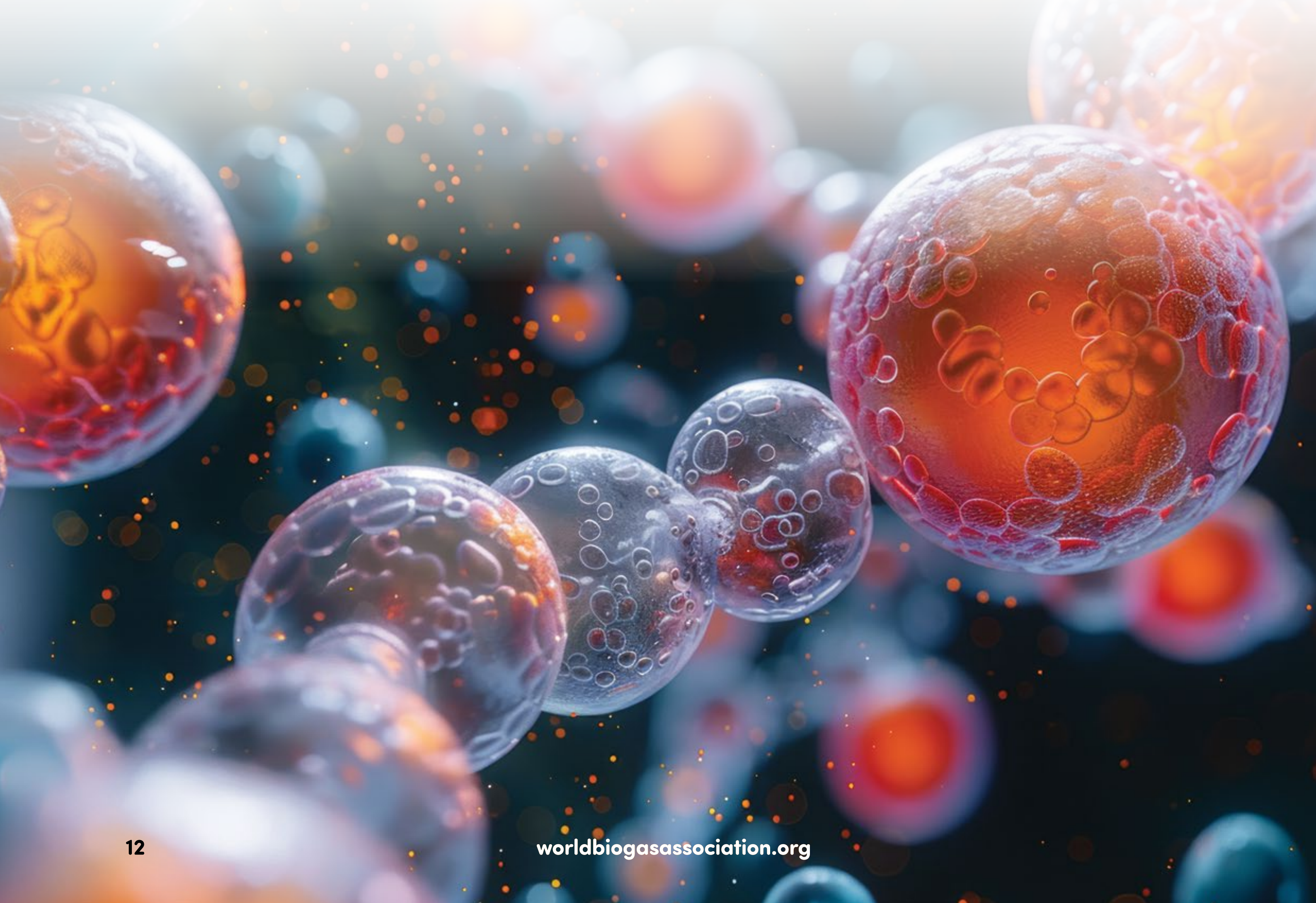


Conclusion

The correct selection and application of an additive for a digester has the potential to drastically alter the digester output. The best additive for a given facility will depend on several factors, such as availability of the additive, the facility hardware, and the feedstocks of the plant. A brief summary of additive, key requirements and main benefits are given below. We trust that the information provided in this paper serves as a good primer for digester operators so that they can now find the best additive for use in their facility.

Additive	Key requirements	Main benefit
Microorganisms	Careful assessment of AD inputs and parameters necessary to select the correct microorganisms	Catalyse hydrolysis. Stabilise methanisation. Can adapt to changes in AD conditions. Can be self-sustaining.
Chemical	Excessive dosing can be detrimental, causing toxicity or precipitation	Better microbial activity through trace element supplementation. Improved substrate biodegradability through chemical pretreatment.
Biochar	Selecting the correct dosage and biochar feedstock	Boosted methane yields and better system stability
Enzymes	Good temperature and pH control	Accelerate biogas stages, particularly the hydrolysis step

Table 1. Summary of types of additives, key requirements and main benefits.



Glossary

AD: Anaerobic digestion.

Additive: A substance or material intentionally added to the digester to improve AD performance. It can enhance microbial activity, stabilise pH, reduce inhibition, or increase gas yield.

Anaerobic digestion: a biological process in which microorganisms decompose organic matter in extremely low concentrations of oxygen, generating biogas and nutrient-rich digestate.

Archaea: A domain of single-celled microorganisms characterised by the lack of a membrane-bound nucleus and organelles, distinct from bacteria. In AD, methanogenic archaea are responsible for producing methane during the final stage of the process.

Bacteria: A domain of single-celled microorganisms characterised by the lack of a membrane-bound nucleus and organelles. In AD systems, bacteria are the primary drivers of the early stages of organic matter breakdown, thanks to their metabolic diversity.

Biogas: A renewable gas produced through anaerobic digestion, primarily composed of methane (CH_4) and carbon dioxide (CO_2), with trace amounts of other gases such as hydrogen sulphide (H_2S) and water vapour.

Biomethane: Purified biogas in which most carbon dioxide and impurities have been removed, resulting in a methane-rich gas with properties similar to natural gas, suitable for compression, liquefaction and injection into gas grids.

Digestate: The residual material remaining after anaerobic digestion. It is rich in nutrients such as nitrogen, phosphorus, and potassium and is commonly used as a biofertilizer or soil amendment.

Digester: A sealed reactor or tank designed to maintain the oxygen-free conditions required for anaerobic digestion, where microorganisms break down organic material to produce biogas.

Enzymatic solutions: Commercial or formulated mixtures containing enzymes (and sometimes microorganisms) added to digesters to accelerate the breakdown of complex organic matter (e.g., fats, proteins, cellulose).

Enzymes: Biological catalysts (proteins) produced by microorganisms that speed up chemical reactions. In AD, they break down complex compounds into simpler ones e.g. cellulases break down cellulose into sugars, proteases break down proteins into amino acids and lipases break down fats into fatty acids.

Feedstock: Organic material fed into the anaerobic digester. Microorganisms break it down to produce methane (CH_4) and carbon dioxide (CO_2).

Funghi: Microorganisms capable of decomposing complex organic materials such as lignocellulose, sometimes used in pretreatment or biological enhancement of organic waste degradation.

Methanogenesis: The final stage of anaerobic digestion (Hydrolysis – Acidogenesis – Methanogenesis) in which methanogenic archaea convert substrates such as hydrogen, carbon dioxide, and acetate into methane.

Nutrients: Essential chemical elements required by microorganisms to grow and function in anaerobic digestion, including nitrogen, phosphorus, trace metals, and vitamins.

Organic matter: Carbon-based material derived from living or once-living organisms, including plant residues, animal manure, and food waste, which serves as the primary feedstock for anaerobic digestion.

Sulfate-Reducing Bacteria: A group of anaerobic microorganisms that use sulphate (SO_4^{2-}) instead of oxygen for respiration. In AD, they compete with methane-producing archaea for organic substrates and hydrogen, reducing the resources for methanogens and negatively impacting methane production.

Syntrophic relationships/interactions: A cooperative metabolic relationship between different microorganisms where one species depends on another to consume metabolic products, enabling reactions that would otherwise be energetically unfavourable, which is critical for stable anaerobic digestion.

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+44 (0) 20 3836 5885 e **policysupport@worldbiogasassociation.org**