
CAVIMAX®

# Biogas Pre-treatment Options

## *The Engine Room*

**03.07.2019 Birmingham, England**

**10.45 – 11.30**

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www.cavimax.co.uk

UK AD AND WORLD BIOGAS EXPO 2019

# AD plant pre-treatment options

**Thermal pre treatment**

Steam explosion

**Chemical pre treatment**

Alkali pre treatment

Acid pre treatment

Oxidative pre treatment

**Mechanical pre treatment**

Knife mills and shredders

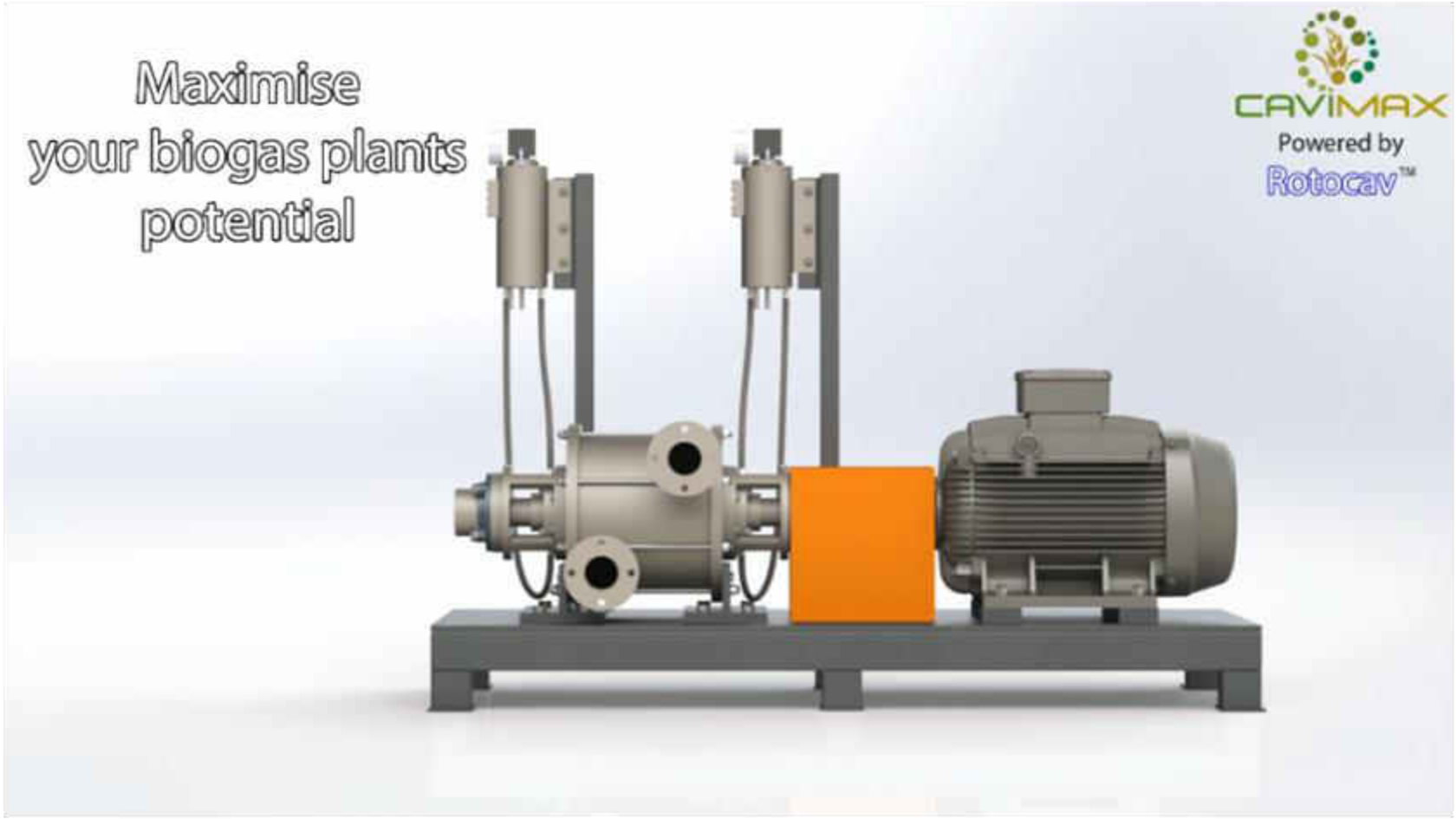
Hammer mills and other systems

Or something else **Ultrasonic or Hydrodynamic cavitation**

# COMPARING ANAEROBIC DIGESTION FEEDSTOCK PRE-TREATMENT TECHNOLOGIES

| Process | Advantages | Disadvantages |
|---|---|---|
| **Milling** | • increases surface area<br>• makes substrate easier to handle<br>• often improves fluidity in digester | • increased energy demand<br>• high maintenance costs / sensitive to stones etc. |
| **Hot water (TDH)** | • increases the enzyme accessibility | • high heat demand<br>• only effective up to certain temperature |
| **Alkali** | • breaks down lignin | • high alkali concentration in digester<br>• high cost of chemical |
| **Microbial** | • low energy consumption | • slow<br>• no lignin breakdown |
| **Enzymatic** | • low energy consumption | • continuous addition required<br>• high cost of enzymes |
| **Steam explosion** | • breaks down lignin and solubilises hemicellulose | • high heat and electricity demand<br>• only effective up to certain temperature |
| **Extrusion** | • increases surface area | • increased energy demand<br>• high maintenance costs / sensitive to stones etc. |
| **Acid** | • solubilises hemicellulose | • high cost of acid<br>• corrosion problems<br>• formation of inhibitors, particularly with heat |
| **Hydrodynamic Cavitation** | • breaks down lignin<br>• increases surface area<br>• measurable improvement | • sensitive to stones |

# Cavitation technology for efficient biogas production



# Cavitation technology for efficient biogas production

**Who and what is CaviMax?**

**What is CONTROLLED hydrodynamic cavitation?**

**Hydrodynamic cavitation for disintegration of lignocellulosic and fibrous feedstocks and recalcitrant substrates**

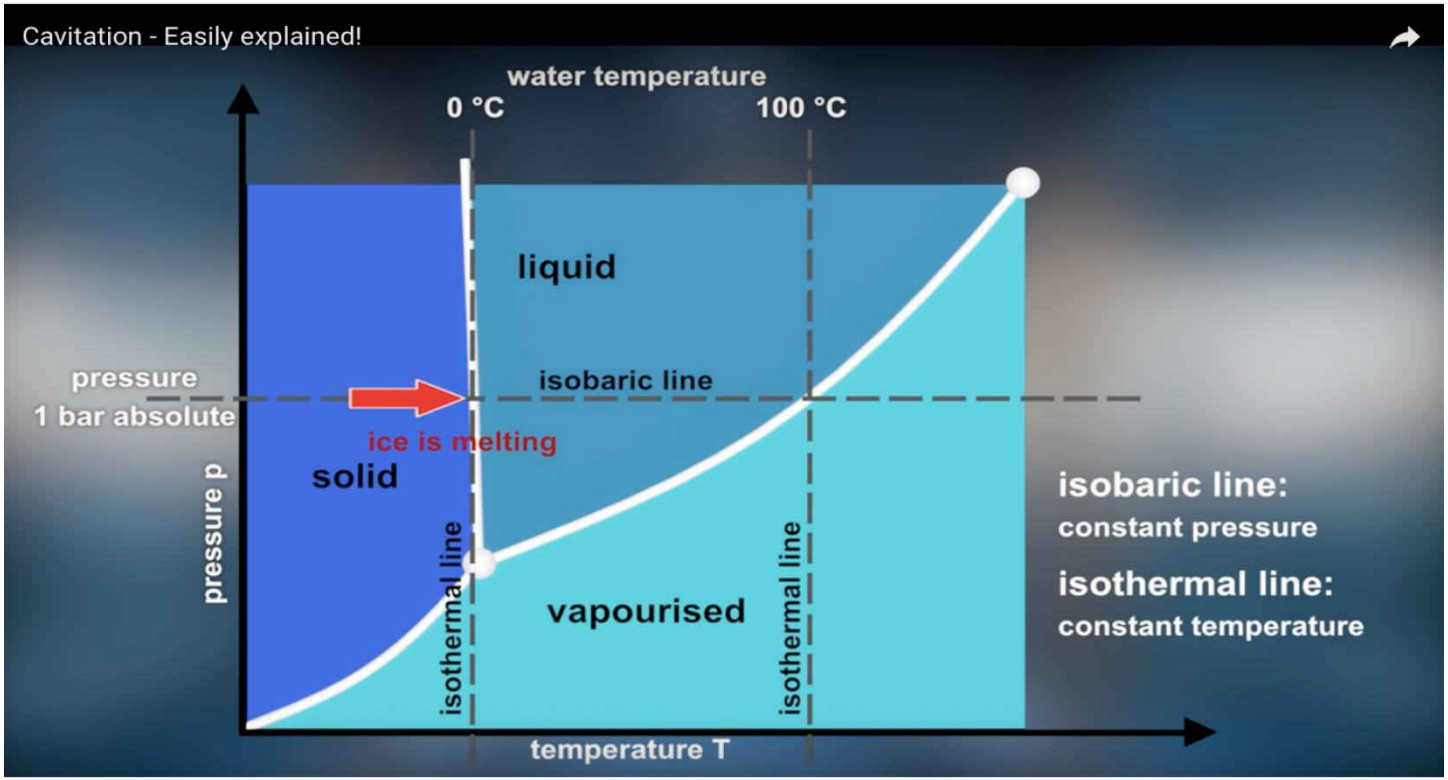
**CaviMax – Our experiences and what the effects look like**

**Benefits of cavitation for anaerobic digestion and renewable gas sector**

What we have found in our industrial trial

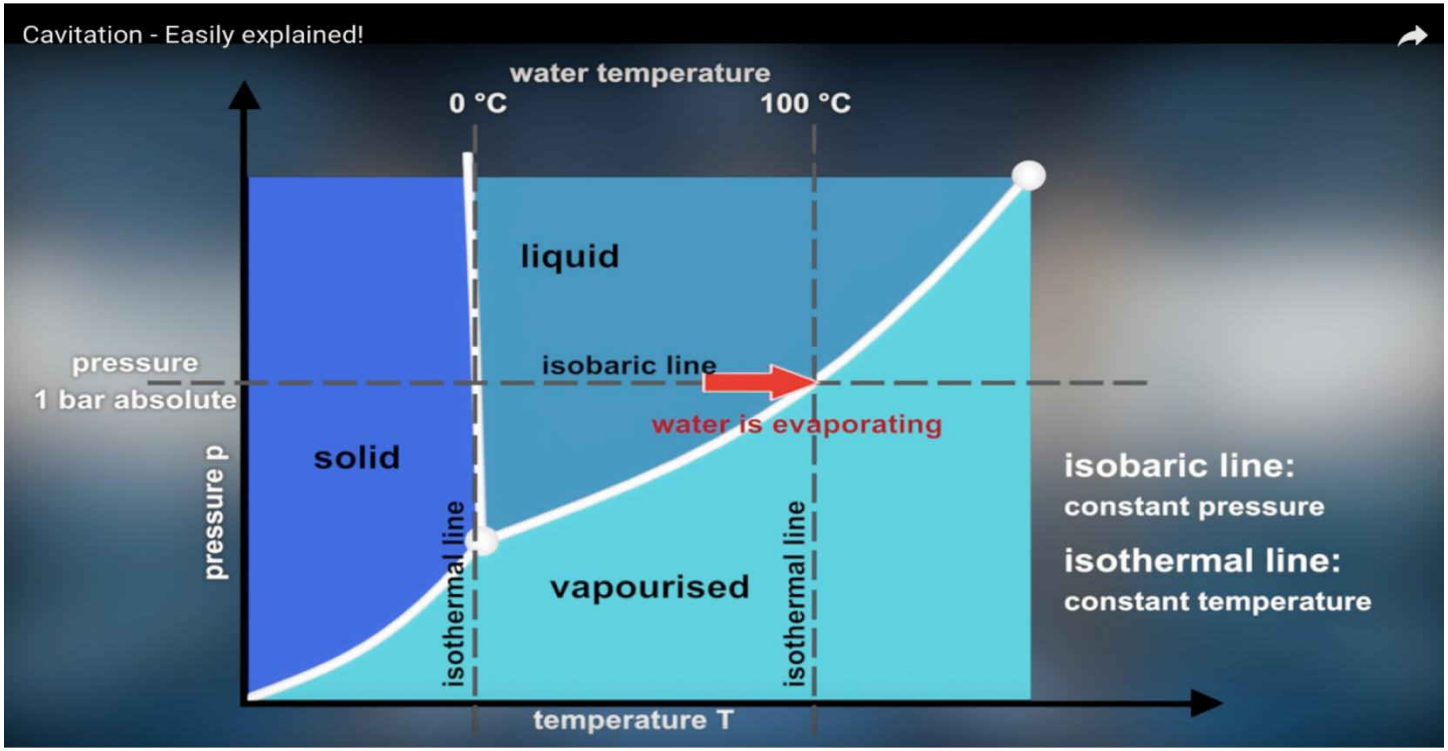
# Cavitation Explained

**Vapour Pressure Curve -** pressure determines the temperature that solids/liquids/gases change phase i.e. reduce atmospheric pressure by half in a vacuum flask of water, the boiling point of the water is reduced to 50oC, increase the pressure to increase the boiling point.



# Cavitation Explained

Vapour Pressure curve - **control the pressure to manipulate the boiling point of liquids –** create the conditions for bubble formation and collapse - microjet



# Hydrodynamic cavitation

Imploding bubbles create millions of high pressure microjets in the chamber

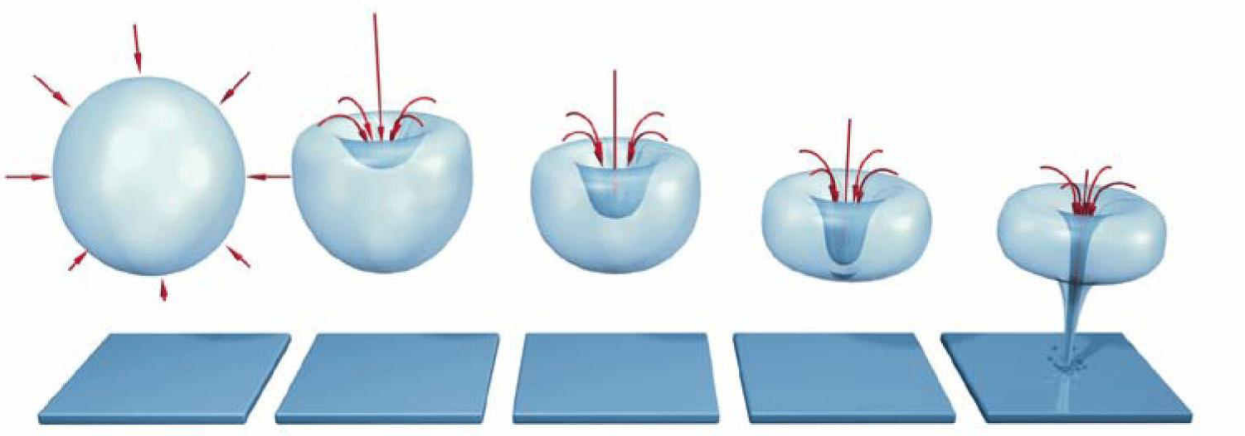
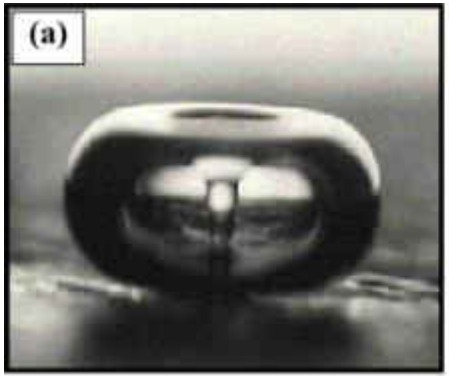
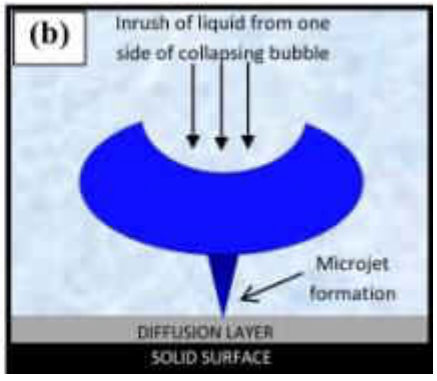


Fig. 1 - Illustration of an imploding cavity in a liquid irradiated with ultrasound

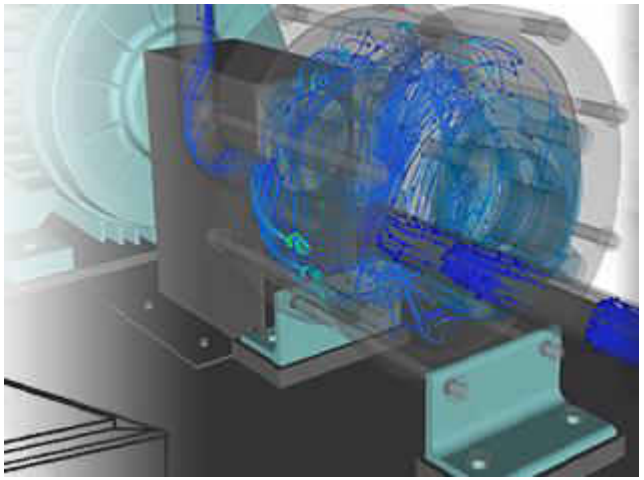


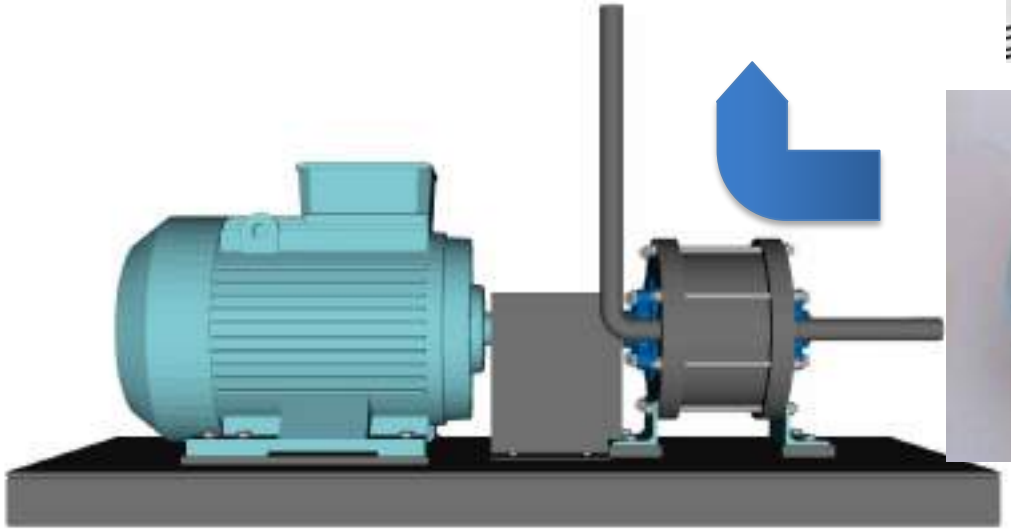




**Asymmetric bubble collapse causes high pressure microjets in the liquid these project their energy into the particles in the substrate, causing collateral damage to surrounding biomass / solids**

# CaviMax – The Biomass Disintegrator

Inside the cavitation chamber – liquids pumped at speed through a spinning rotor-stator, this creates pressure differentials in the liquid



# What can the CaviMax Biomass Disintegrator treat in the biogas plant?

- **High lignin feedstocks – agricultural residues**
- **Secondary sewage sludges**
- **Food and drink production waste**
- **Floating layers**
- **Part digested substrate, still energy in digestate**

**The greatest biogas % increase is achieved through treating only the recalcitrant materials that are indigestible, unusable and the energy usually wasted**

# What do the effects/results look like?

Reduced particle sizes & viscosity

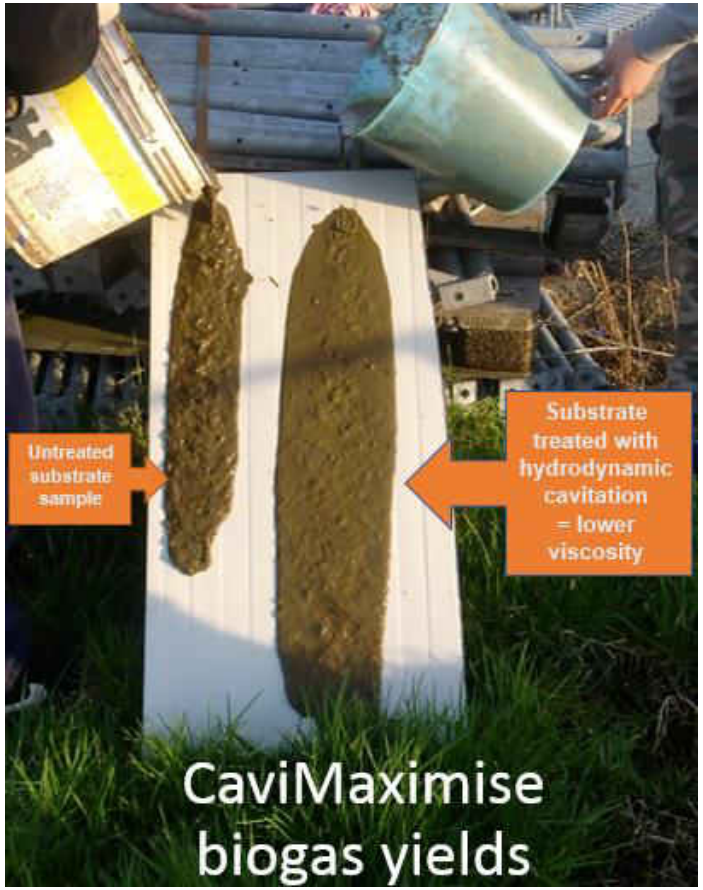
Sample from maize fed AD plant recirculating substrate line – fed back into the same digester

Before cavitation – see lots of fibres and solid material left in the hand after squeezing the water out of the sample

After cavitation – much less left in the hand after the squeeze test

# What do the effects look like?

Cavitated sample on the right uncavitated on the left – see **reduced viscosity**, thinner, less particles, freer flowing




# What do the effects look like?

The **jar settle test**, give the samples a shake and see how long the particles take to settle, left is non cavitated, middle and right, I x cavitation pass, and multiple cavitation passes

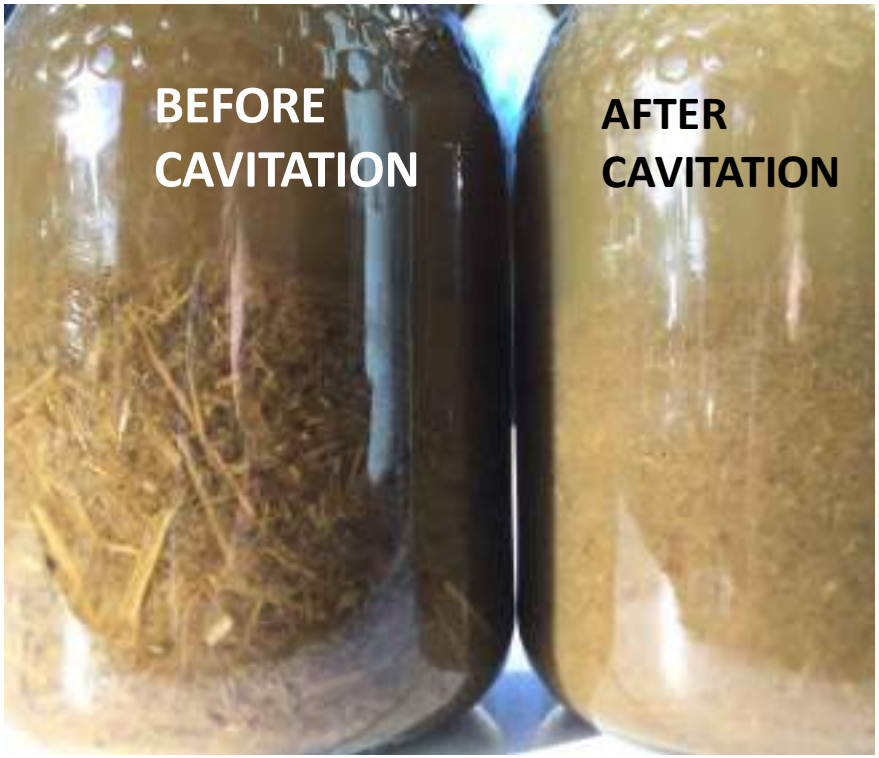
Non cavitated settles straight away, cavitated small particles stay in suspension for days and weeks

After many weeks the non cavitated sample turns into a floating layer, the cavitated samples are like fine silt, some particles are so small they are still in suspension

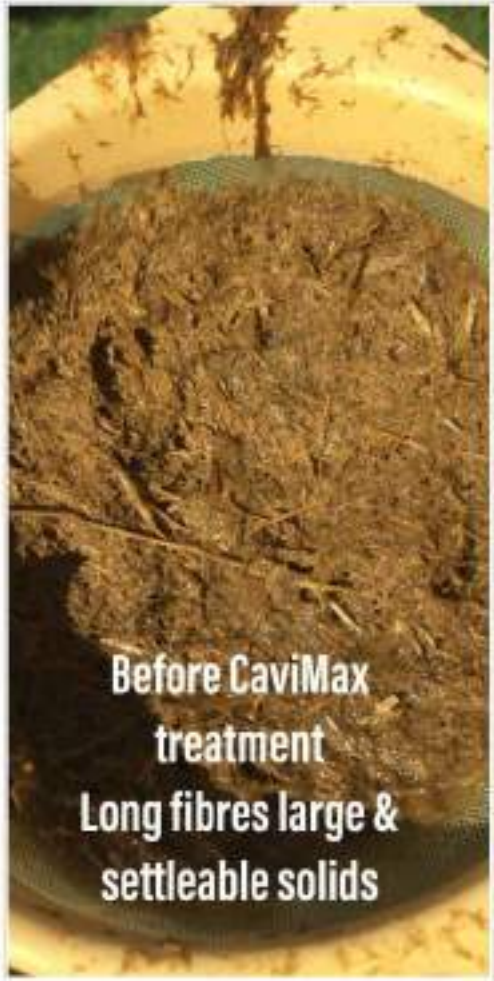
Trial feedstock = paunch manure (undigested gut contents of cattle)

# What do the effects look like?

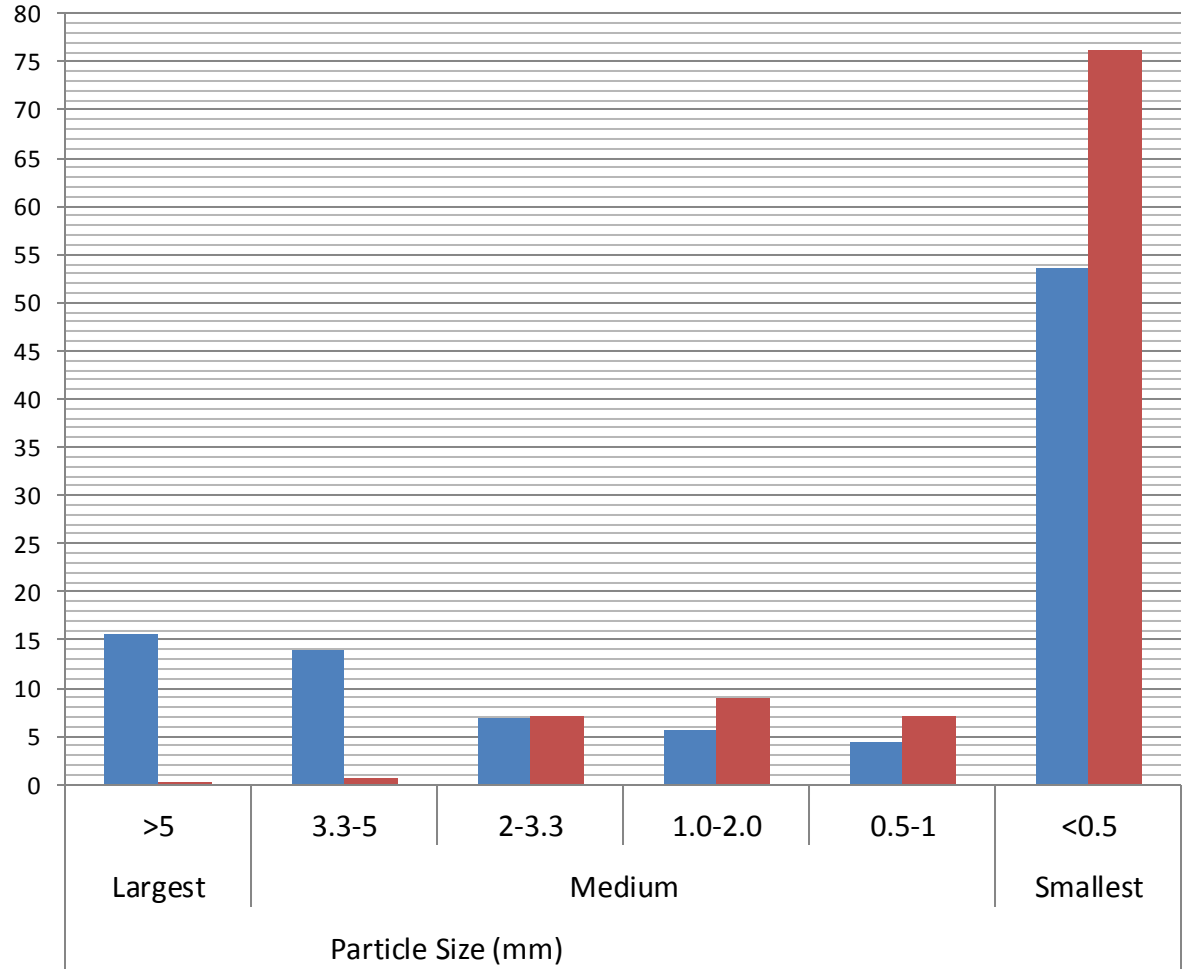
The treatment has a visible effect – **smaller particles**




The large particles are reduced, the smaller particles are also reduced and homogenised




# Effects of cavitation – reduction in particle sizes




**Same dry matter content, however particle sizes are redistributed**

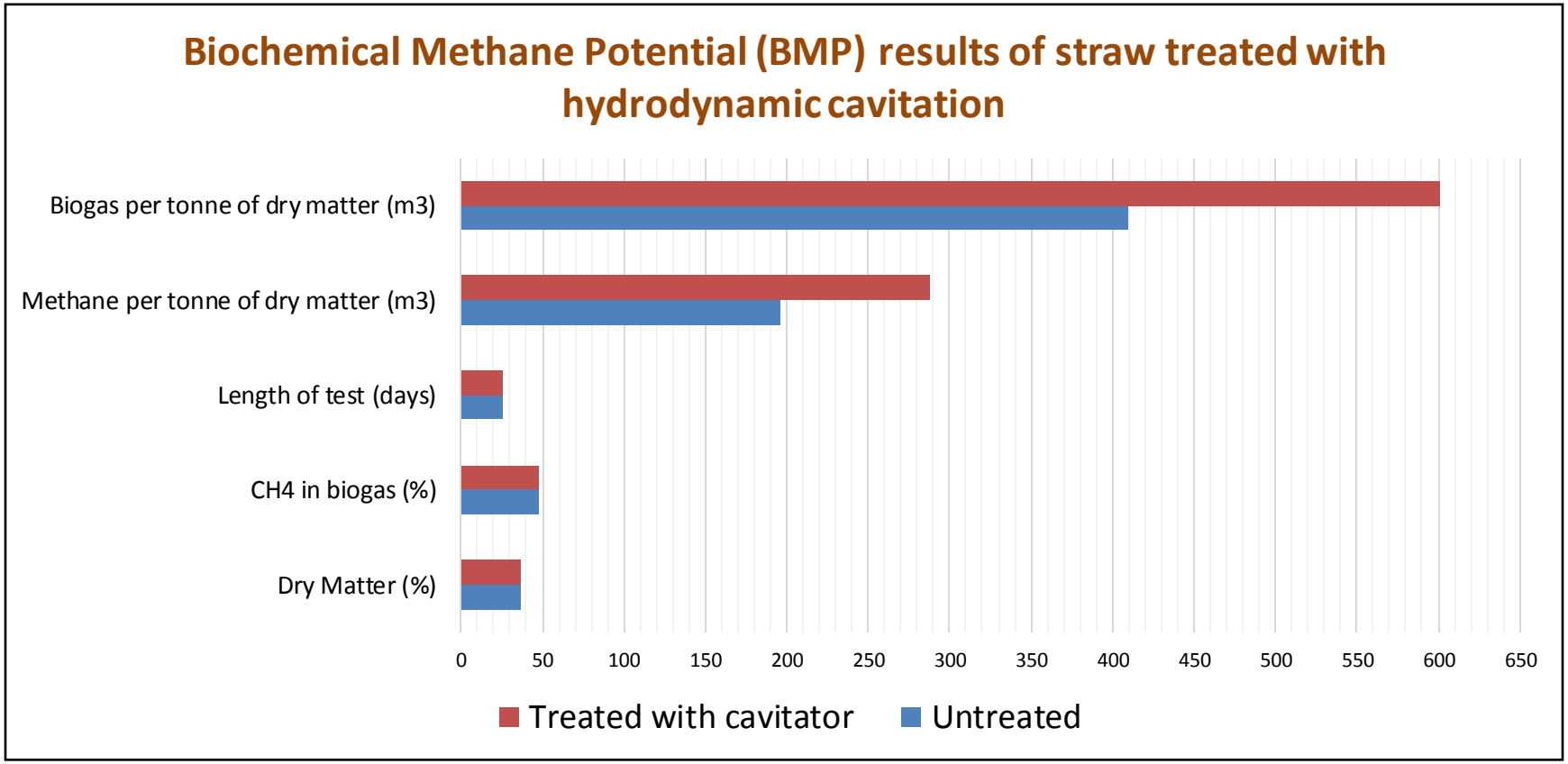
# Results of cavitation - increase in biogas and methane

## Biochemical Methane Potential (BMP) Test - STRAW

| Batch test results - STRAW | Untreated | Treated with cavitator | % change |
|---|---|---|---|
| Dry Matter (%) | 36.31 | 36.31 | 0% change |
| CH4 in biogas (%) | 47.8 | 47.8 | 0% change |
| Length of test (days) | 26 | 26 | 0% change |
| Methane per tonne of dry matter (m3) | 195.9 | 287.4 | 68% increase |
| Biogas per tonne of dry matter (m3) | 409.8 | 601.2 | 68% increase |

**methane percentage increase in cavitated sample = 68%**

# Pre-treating straw with HDC results in a viable feedstock



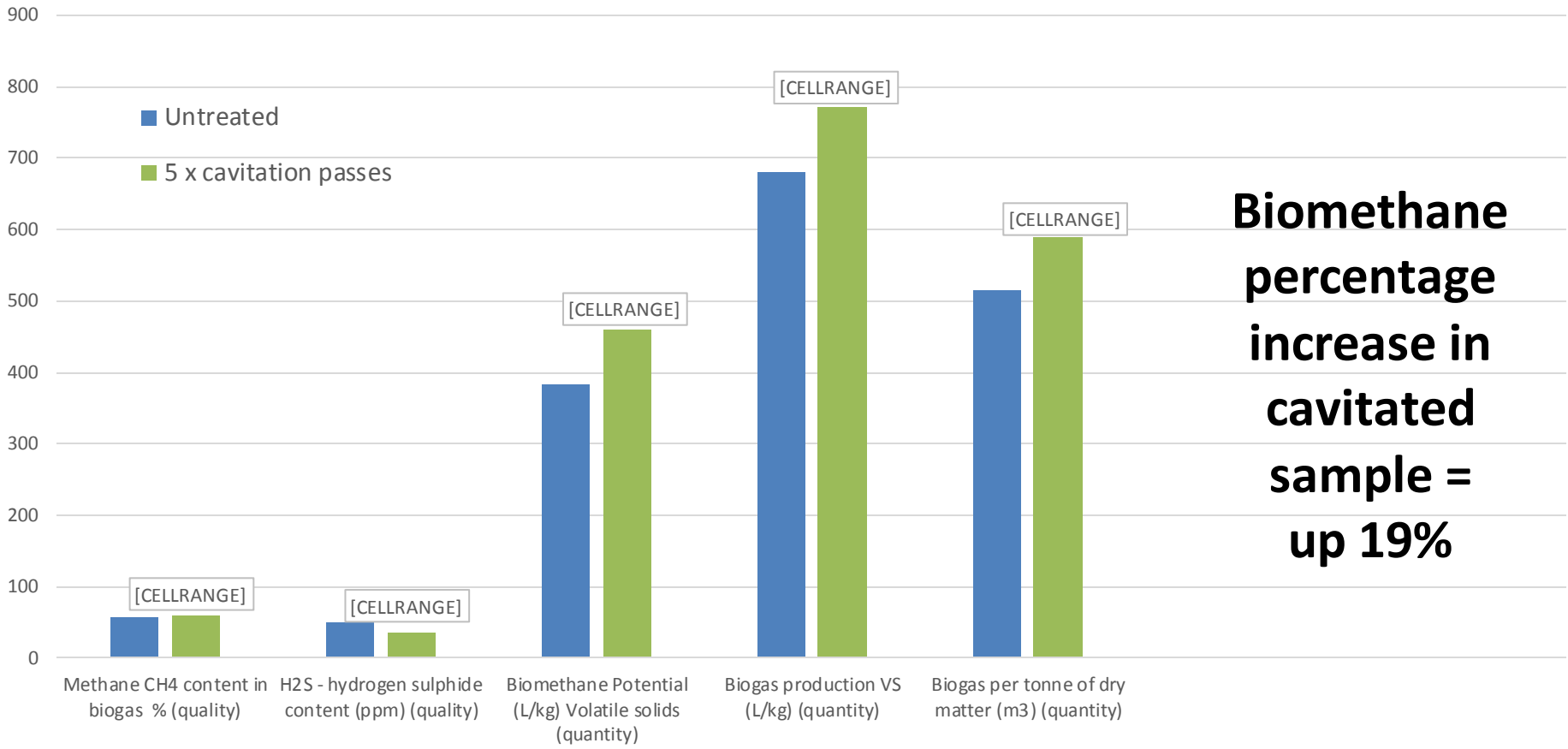

**methane percentage increase in cavitated sample = up 68%**

# Treatment of Hydrolysed sewage sludge

| BMP test results - Hydrolysed sludge Water utilities sludge plant | Untreated | 5 x cavitation passes | % change |
|---|---|---|---|
| Methane CH4 content in % biogas (quality of the biogas) | 56.5 | 59.4 | 5% increase |
| H2S - hydrogen sulphide content (ppm) (quality) | 51.0 | 35.0 | 31% decrease |
| Biomethane Potential (L/kg) Volatile solids (quantity of the biogas) | 384.2 | 459.1 | 19% increase |
| Biogas production VS (L/kg) (quantity) | 680.1 | 772.7 | 14% increase |
| Biogas per tonne of dry matter (m3) (quantity) | 515.9 | 589.9 | 14% increase |

**methane percentage increase in cavitated sample = up %**

# Hydrodynamic cavitation treatment of Hydrolysed sewage sludge




**Biomethane percentage increase in cavitated sample = up 19%**

**Hydrogen sulphide decrease in cavitated sample = down 31%**

# Where does it fit in? CaviMax positioned mid-process – treating the floating layer

Draw off floating layer from the top of the digester pass through CaviMax to homogenise the substrate

Return cavitated substrate back to the bottom of the digester for further digestion which increases flow and bioavailability of the substrate

**Access the energy of undigested feedstocks**

# Where does it fit in?
# CaviMax positioned to pre-treat high lignin feedstocks

Traditional feedstocks

Primary digester

High lignin feedstocks


Feed in system

CaviMax

To secondary digester / end store

Recirculate digestate to hydrate feedstock to create pumpable substrate

**Unlock the potential of straw, grass silage, residues**

# Where does it fit?
# CaviMax positioned mid-process between digesters

Primary digester

The CaviMax in this position will reduce particle sizes of the substrate, providing increased plant efficiencies and biogas yield

Secondary digester

Ideal position to treat recalcitrant materials that did not get fully utilised in the primary digester – extract maximum value from your substrate

**energy crops / secondary sludges in waste water treatment / food and drink waste / undigested fractions of feedstocks**

# Benefits of cavitation for biogas plant operation

- Reduce feedstock costs or increase biogas production
- Ability to digest high lignin feed stocks – utilise straw
- Decrease problematic floating layer – important when dealing with grass and straw (crust reduction in digester)
- Increased availability of cellular juices
- Acceleration of hydrolysis & the anaerobic digestion process
- Reduce retention time in digester
- Increased pumpability of substrate
- Reduced plant downtime due to blockages
- Reduction in $H_2S$ pollution, plant degradation & hazard

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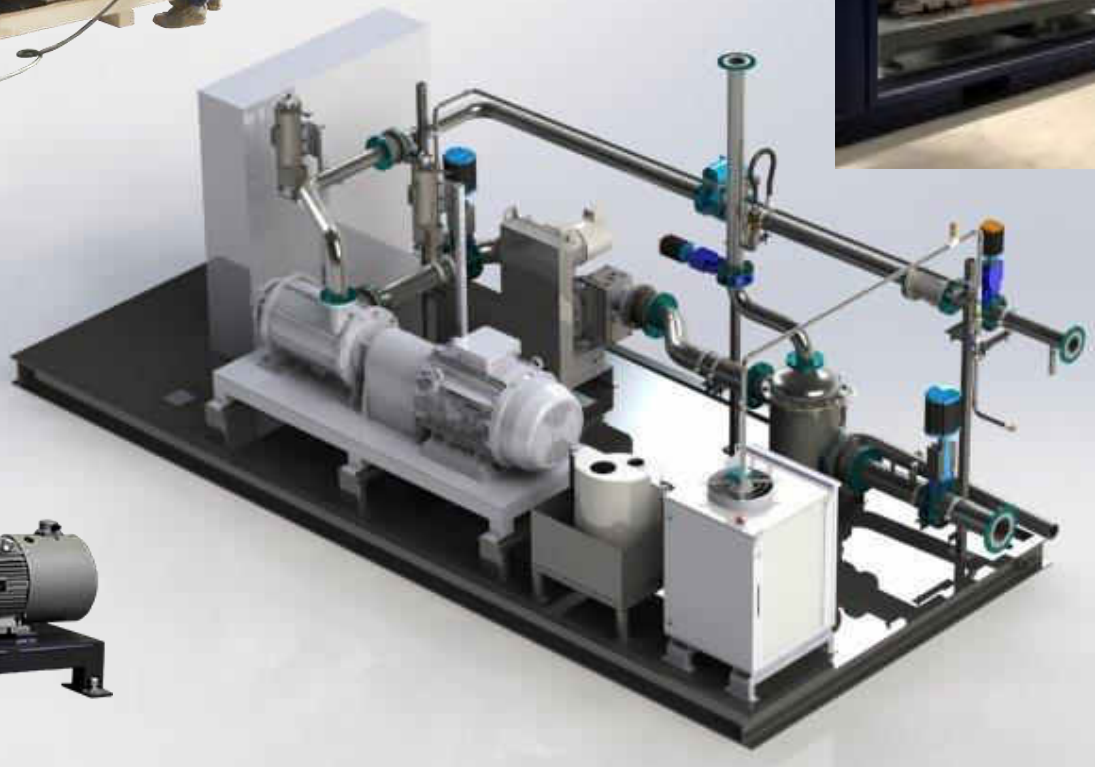
# Process intensification technology
# Fit a CaviMax to optimise



# send us your samples

Send us a sample to cavitate or book The CaviLab, a laboratory scale test rig to see what process or BMP (Biochemical Methane Potential) uplift you can achieve with a CaviMax machine

# Thanks for listening

Team CaviMax have years of experience in planning, designing, building, operating, managing and maintaining biogas / biomethane plants, come discuss your plant with us to see how we can CaviMaximise your biogas plants operation

**Owen Yeatman – Director**

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**Emma Greenwood – Business Development Manager**

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