KINETIC BIOFUEL

BOOSTING SUSTAINABILITY

STRAW FOR BIOGAS AT INDUSTRIAL QUANTITIES IS A LOGICAL AND TECHNICAL CHALLENGE

SOLVED BY KINETIC BIOFUEL BRIQUETTING SYSTEMS!

Pre-treatment of straw to high density briquettes via mechanical briquetting is core of this technology



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THE ANEAROMIC FERMENTATION

Cereal straws are the single largest energy resource for anaerobic digestion (AD) and biogas production; straws are produced in millions of tons annually in most European countries and globally. Often, the quantity adds up to 10-20% of any given nations gross energy consumption and may potentially cover most natural gas consumption of many nations. In addition, straws are lignocellulosic crop residues available for AD without taking up agricultural land, and therefore without compromising food or fodder production.

Lignocellulosic biomass feedstocks are typically dispersed over a wide geographic area and must be collected and transported to processing facilities. Previously, the predominant mode of biomass collection has been compression into large bales, typically having densities on the order of 150 kg/m3.

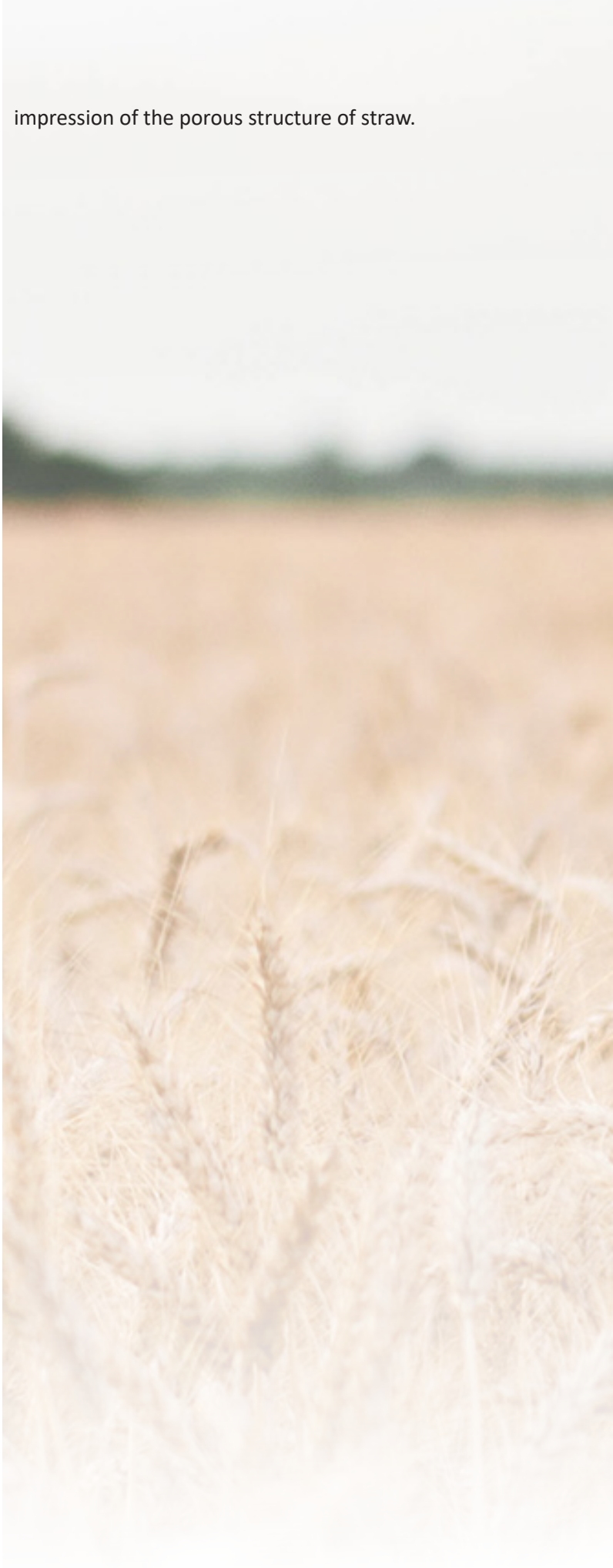
We have developed a cost-effective technology compressing biomass into briquettes at densities of 1000 kg/m3. This compression, or "briquetting," process, imparts significant force to the feedstock, resulting in transient local high temperatures that accomplish a significant physical transformation of the fibrous material. The dense briquettes can then be transported to processing facilities at much lower cost, where one vehicle can transport 3-4 times the quantity of biomass in a single load.

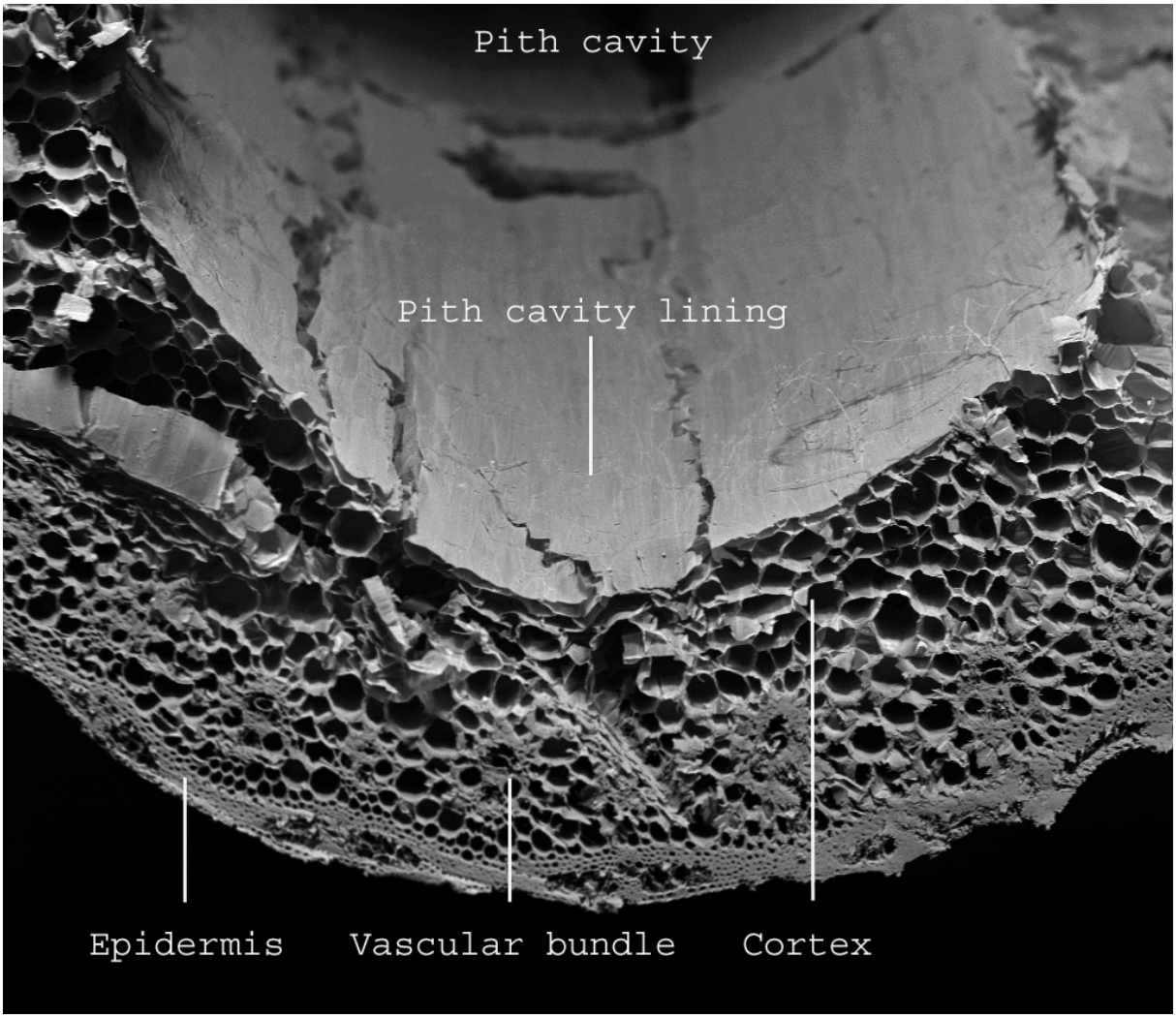
With this new technology, the bottleneck of large-scale cellulosic biofuel production is overcome paving the road to substantial, robust, and profitable biogas production in Europe and elsewhere.

CEREAL STRAWS

Cereal straws are constructed to withstand the ambient conditions in the agricultural fields, and attacks by pests, microorganisms, enzymes, and water; and straws are built very well to that end. Straws are constructed with air-filled pores from nano- to meso-scale and to macro-scale. For these reasons, straw cannot directly be used for anaerobic digestion; an effective and targeted pre-treatment is necessary.

The pre-treatment must provide access for water and enzymes to the surfaces of straw. Here, it is essential to note, that 80% of the surface area of straw is found in the smallest of pores, the nano-pores, and virtually all surface areas in pores as such. The picture on page 2 gives a good impression of the porous structure of straw.

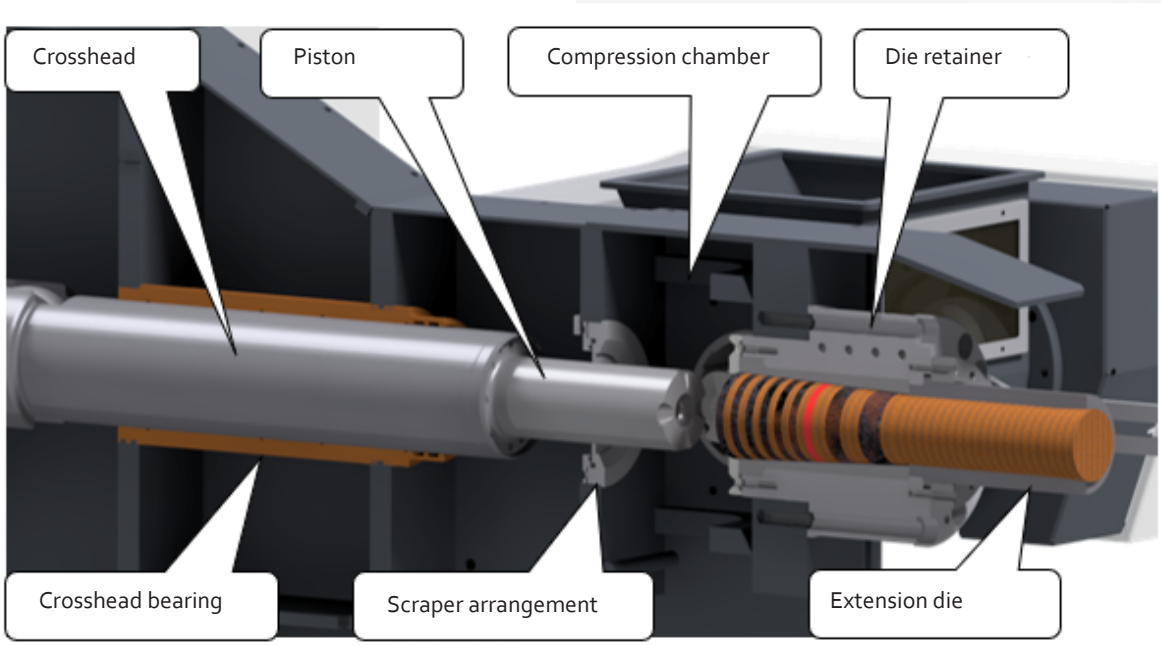




Straw consists of pores from nano- over meso-scale and to macroscale.
From Hansen et al. Bioresource Technology 102 (2011) 2804–2811

PRE-TREATMENT VIA BRIQUETTING

Mechanical briquetting is a technique by which a reciprocating piston compresses the straw at high pressures in matter of split seconds – literally. The straw is compressed to a very high specific density. In other words, lose falling straw weighs approximately 50 kg per m3, while briquettes weigh 1000 kg per m3, the bulk density being around 500 kg per m3



The briquetting also alters the properties of straw in a number of distinct and surprising ways. The advantage relative to use as raw material for biogas includes the following:

MANAGING AND FEEDING STRAW DIRECTLY INTO BIOREACTORS

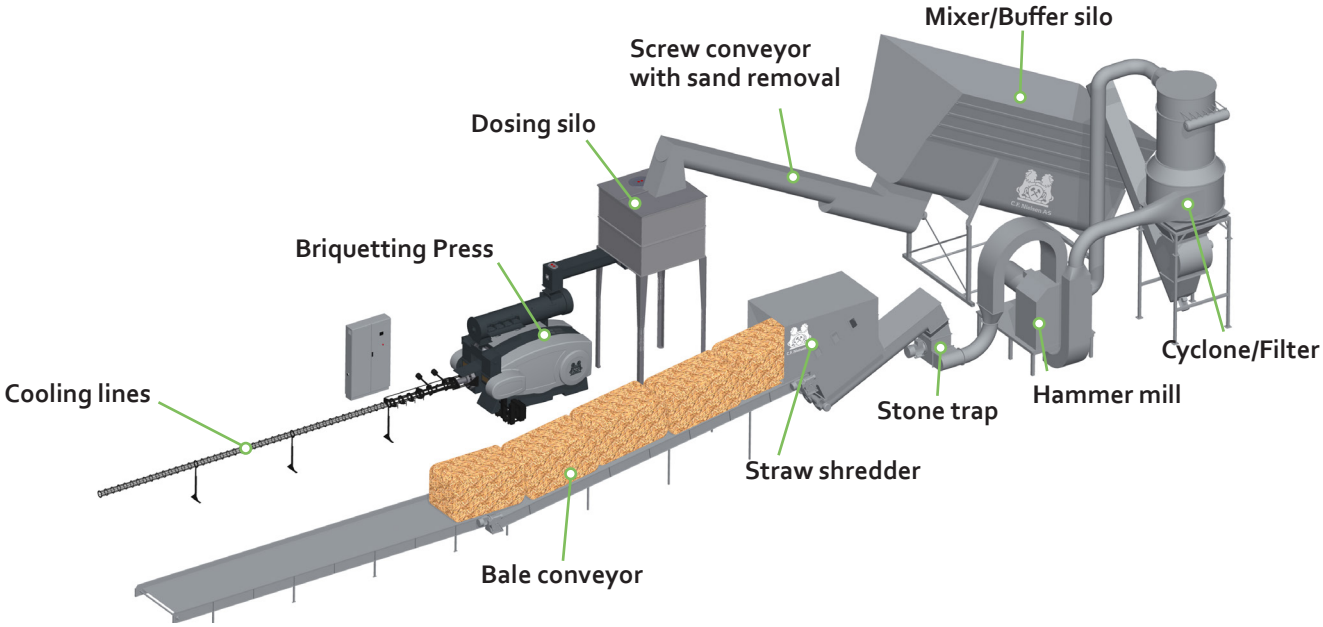
The briquetting offers a systems solution for actual receiving big bales of straw, managing the bales, and feeding in big bales of cereal straw as high-density briquettes directly into the bioreactors.

A briquetting line consists of a straw-line including conveyor band for (big bales, shredder, stone and sand trap, a hammer mill before the actual briquetting and direct feeding into the biogas reactor. Direct feeding is possible due to the altered properties of the straw.

It has been demonstrated for more than 3 years at the biogas plant at Aarhus University full scale experimental facility at Foulum, that substantial quantities of straw briquettes can be directly injected into the reactors.

A remote satellite station may also produce briquettes in areas with surplus of straws for subsequently transport of the briquettes to one or several biogas plants. Such satellite stations can be designed with one or several briquetting presses and at any capacity between 10.000 to 150.000 tons annually.

The briquets can simply be received at the biogas plant directly in a hopper or bio mixer, and from here be injected into the bioreactors. No further management is needed. Here the briquettes may replace energy crops or simply add to the biogas output.







Lose straw (50 kg / m3) and briquetted (1000 kg/m3). The newest developed briquette press of high capacity dedicated to biogas and bioethanol purposes (the BP7510 model).

THE STRAW PORES ARE EXPLODED

Because all pores of the straw are exploded and water can penetrate into the straw, it also renders access for microorganisms and enzymes actually digesting the straw into biogas.

This ensures a relatively quick and effective digestion in the biogas plant.

STRAW BRIQUETTES ARE EVACUATED OF AIR

The compressed straw is emptied for atmospheric air, notably free nitrogen and oxygen, and air is therefore not added to the biogas when using straw briquettes. This is highly advantageous when the biogas is upgraded to natural gas quality and liquid CO2.

WATER ABSORPTION - THE SPONGE EFFECT

One remarkable and visible effect is that straw is rendered highly water absorbent due to the briquetting treatment. It is therefore easily suspended and dispersed in the bioreactor liquid, when added to a bioreactor. Because water penetrates into the straw matrix, the soaked straw absorbs up to 10 times its own weight, and achieves the same density as water. It will distribute evenly in the reactor volume. No floating covers will develop, no sediments, dead volumes or clogging will appear.

Addition of straw briquettes does not require additional stirring effect.

STRAW BRIQUETTES DO NOT IMPACT THE HYDRAULIC CAPACITY OF ANY BIOGAS PLANT

The direct feeding of dry briquettes into bioreactors does not impact the hydraulic capacity of the biogas plant simply because only dry matter is added (with 10-15% moisture as opposed to slurry with 90-95% moisture).

It is unnecessary to suspend the briquettes in raw manure or digested manure under severe stirring or such before adding to reactors. No extra tanks fitted with stirrers are needed.

Generally, it is an advantage of having relatively high central stirred tanks rather than relatively flat tanks with side fitted stirrers when reactors are run with high dry matter contents.



Caption:
On the left a briquette is dissolved in water, on the right the same amount of straw floats on top.

THE STRAW PLANT, OR SATELITE STATION, MAY BE SITUATED LOCALLY AT THE STRAW-RESOURCE OR AT THE BIOGAS PLANT

Local circumstances and conditions will determine if it is advantageous to develop satellite stations for local collection and processing of straw into briquettes before storing and transporta-tion to one or more biogas plants.

AN ENERGY OPTIMAL PRE-TREATMENT

Briquetting uses very little energy and no water for the pre-treatment. The electrical power use of app. 75 kWh per tons straw all included.

Conventional pre-treatment of straw before a biogas or bioethanol process, such as steam explosion at 180-200 C and 30-40 % dry matter, is a highly water and energy demanding process, which also impacts the hydraulic capacity of the biogas plant negatively.

Briquetting is the effective and economic solution.

A MECHANICALLY ROBUST AND STABLE TECHNOLOGY

Straw inevitably contains gravel, soil, or sand or perhaps other impurities. A straw line removes all impurities before the briquetting. The mechanical press is not exposed for this wear and tear and the impurities are not imported into the biogas facility.

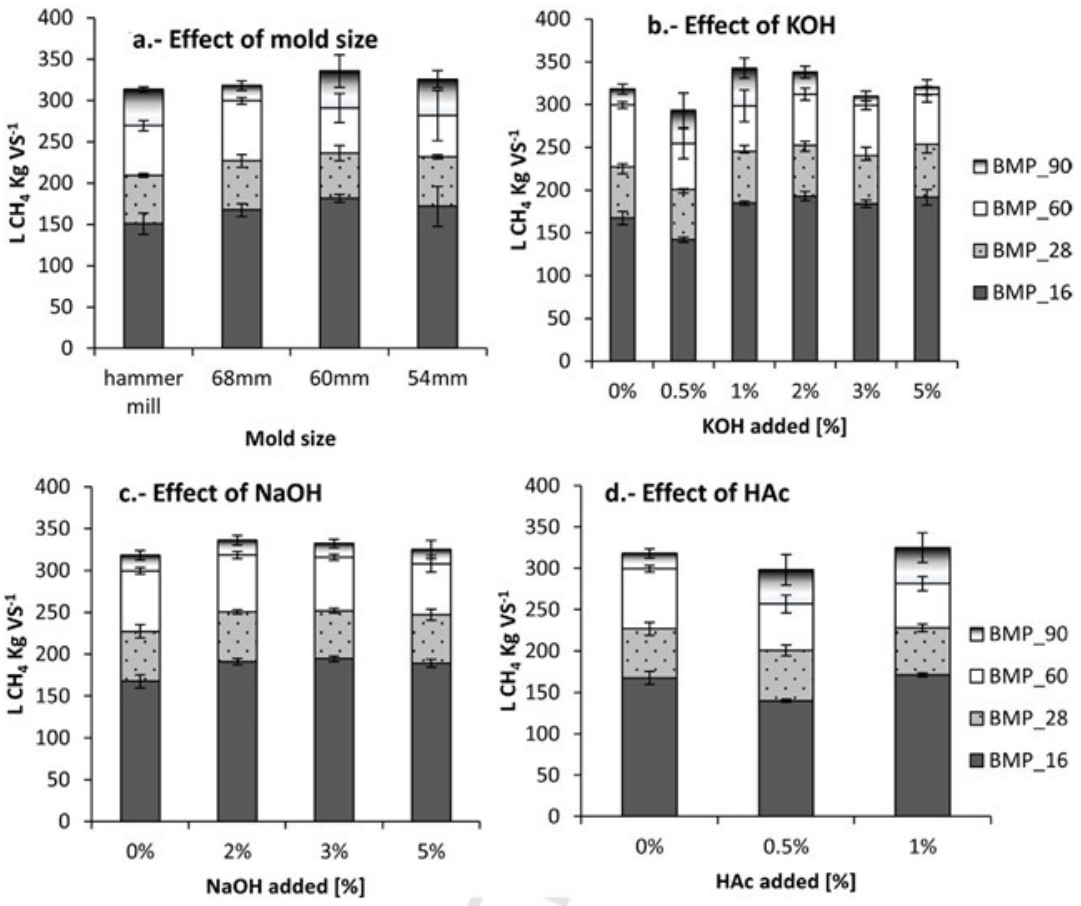
The straw line is easy to manage and service, and functions fully automatic.

BIOMETHANE POTENTIALS

When estimating biogas yields of various substates, generally biomethane potentials (PMP) are measured by laboratory incubations. We have measured several hundreds of BMPs of briquetted straw and generally find a MBP yield of 300-350 litre per kg volatile solids (VS). We find this level with different mould size or with or without catalyst indicating that straws inherently are relative digestible if they can be added to the bioreactors, hence the briquetting allowing for exactly that, adding into a bioreactor. Below are a number of such PMPs displayed in the figure.

Potential methane yield from briquetted straw as function of dye size (and thus kinetic energy dissipation) and use of catalyzer. From Veronica Moset et al (2015) Optimization of methane yield by using straw briquettes- influence of additives and mold size. Industrial Crops and Products. Volume 74, 925–932. (See model on page 7.)





HIGH BIOGAS YIELD

Briquetted straw gives rise to high and stable biogas yields.

Straw generally contains 20 MJ/kg volatile solid (ash free organic matter) dry matter primary energy corresponding to app. 500 Nm3 methane per tons volatile solids of primary energy!

The straw composition is 60-70 % cellulose and hemicellulose, 15-20 % lignin, other organics (5-10 %) and minerals (app. 5 %). Normally, it is the bulk of cellulose and hemicellulose, which, after briquetting, is digested into biogas, while lignin is largely un-digested.

With briquetting, biogas yields of app. 250 Nm3 methane per tons straw can be achieved increasing to app. 350 Nm3 methane per tons or more under optimal conditions.

A hydraulic retention time of 30-40 days at thermophilic temperatures is needed to achieve these yields.

The quantity of straw which can be added to manure fed biogas plants – the organic loading rate – is equally important. It is clearly demonstrated that 10 % straw briquettes relatively to the liquid manure can be added without any difficulties. If addition of more straw relatively to manure is warranted recycling of digestate is recommended.

Biogas plant type	Hydraulic residence time (days)	Methane per kg VS (litre per kg VS)	Methane per tons straw (Nm3)
Standard mesophilic	50-80	250	250
Standard thermophilic	30-50	300	250
Thermophilic plus hyper thermophilic	30-50	350	300
Expanded with recirculation	30-50	400	350
Advanced industrial	30	450	400
Straw total energy content		550	
Estimated theoretical maximal methane production		500	450

The achieved gas yield from straw depends mainly on the type of biogas plant and its running mode as estimated: (Gad volume calculated at 25 degrees celsius)

STRAW BRIQUETTES CONTRIBUTE TO A STABLE BIOGAS PROCESS

Several manure-based biogas plants, if not most plants, are at the brink of ammonia inhibition. In any case, it is virtually impossible to add significant quantities of nitrogen containing wastes such as poultry manure.

Straw briquettes help alleviating ammonia inhibition and stabilize the digestion process. An increased yield of slurry is achieved when co-digested with straw briquettes.

This is due to the wide carbon to nitrogen (C/N) ratios of straws as opposed to manures. In general, the mean C/N ratios are optimal in the range of 20-40 for the AD feedstock.

The picture on the right shows the gas yield with manure only and with 8% addition of straw briquettes; it doubles the gas yield.

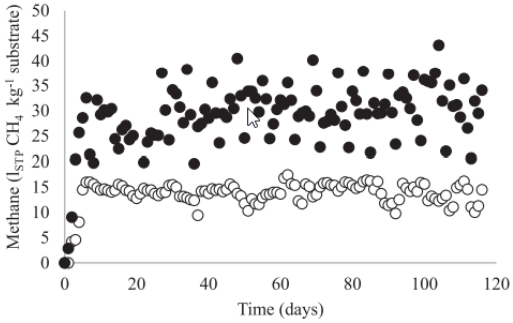


Fig. 3 – Volumetric methane yield obtained in full-scale CSTR from cattle manure (○) and cattle manure and briquetted wheat straw (●).

From Xavier et al (2015) The efficiency of shredded and briquetted wheat straw in anaerobic co-digestion with dairy cattle manure. Biosystems Engineering 139, 16-24.

IMPORTANT REQUIREMENTS FOR A STRAW BRIQUETTING PLANT

- Straw needs to have a moisture level below 15%, above this the productivity will decrease and the briquette quality will be poor. However, loose briquettes are fine biogas raw material
- The raw material has to be clean with as low ash content as possible. Especially, a high sand level will impair operations, as the wear and tear on parts will be high
- The right equipment is required to secure high productivity. It is important to have a full-line supplier to combine all the shown items of the line
- Trained operators. In order to secure high uptime, it is important that the operators are well trained both with respect to machines and raw material handling

Plant size and operational costs

- Plant sizes from 0,5 t/h to 10 t/h or more
- Power consumption for the line approx 100 Kwh per ton produced
- Spare part costs for briquetting with clean raw material – EUR 5-7 per ton
- Labour cost will depend on degree of automatizatio

Advantages for briquetting plants

- High efficiency - 24/7 production.
- Low power consumption.
- Relatively low spare part consumption.
- Low labor costs.
- Optimized use of raw material - the mixer/buffer silo can handle varying moisture levels from 10-18%.



BEDDING FOR BIOGAS

Before the briquettes are introduced into the biogas plant, it is worth considering using the briquettes for bedding by the dung supplier, that way the briquettes will serve a dual purpose:

1. It will serve as a good and effectively absorbent bedding in the animal farm
2. The cell structure is already prepared when deep litter is delivered to the biogas plant
3. The bedding is sanitized and sterilized by briquetting

THE CONCLUSION

The model requires that the machinery service provider handles all logistics and agreements.

It is a win-win-situation:

- The farmers gets cheaper and better bedding
- The biogas plant gets cheaper straw and higher gas yield

BEDDING FOR BIOGAS

AKTUAL MODEL	WITH STRAW BRIQUETTES
Farmer buys shredded long straw at - Index 100	Farmer buys straw briquettes (short straw) for bedding - Index 66
Deep litter is delivered to biogas plant	The bedding is used in shorter time as usual and is sold at Index 66 of briquette prices
The biogas plant will achieve a methane yield which is lower than bedding from straw briquettes	The biogas plant will achieve a methane yield higher than deep litter

BIOFUELS IN GENERAL

The system is optimal also for other biofuels such as cellulosic ethanol, methanol and others:

Through the simple expedient of using briquetted feedstock in a low-cost, unagitated steam pretreatment system, the following improvements in business case for autohydrolysis-based processing is readily achieved:

1. Significantly reduced capital cost for the pretreatment system
2. Significantly reduced tendency for processing bottlenecks at large scale
3. Significantly reduced operating cost from pH adjustment
4. Significantly improved recovery of C5 sugars
5. Significantly reduced toxicity of the soluble component of pretreated biomass against enzyme preparations
6. Reduction of energy consumption during pretreatment
7. Overall ethanol production per tons raw material can be increased by at least 10% simply due to conservation of feedstock through optimal feedstock logistics based on briquetting

SUMMARY

Mechanical briquetting of straw for biogas purposes is the most tested, documented, and safest technology of using straw for biogas purposes.

We are proud to offer this cost-effective solution for industrial utilization of straw for biogas.

In Kinetic BioFuel A/S we are proud of our technology and company and enjoy our work.

For additional information and contacts reference is made to Kinetic Biofuel ApS (www.kineticbiofuel.com) and:



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