

Energy recovery from cellulose fraction of solid waste from recovered paper processing by digestion

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1 Introduction

1.1 Background

Energy savings and sustainable energy production are the prior issues for paper industry. At the same time huge amounts of solid waste are generated from paper recycling. High discharge and landfill cost make the solid waste an important economical factor for the recycling branch of paper industry. One of the possible applications for the stream of waste composing of cellulose fibers seems to be energy recovery. Existing technologies can be hired for these purposes. A concept idea appeared to use the waste materials for bio-gas production. Most of the recycling paper mills are equipped with a combined heat and power (CHP) plant at the location. The bio-gas obtained from solid waste could be applied at the location of those mills. Aforementioned combine solutions for two issues, the problematic solid waste discharge and expensive energy production from fossil fuels.

1.2 Objectives

- Analyze of solid waste's digestibility from recovered paper processing and its application in bio-gas production
- Enzymatic hydrolysis of the cellulose fraction into digestible sugars
- Digestion of sugars—efficiency of bio-gas production

1.3 Target group and materials involved

Residues from recycled paper processing paper mill are to be investigated within the activities of the project. Certain streams of waste with digestibility potential were chosen for the analysis. The materials are to be applied for energy recovery via bio-gas production with the use of existing waste water treatment installation (anaerobic installations).

Samples of certain reject streams to be analyzed are as follows:

- Secondary sludge from Industriewater Eerbeek (IWE)
- Deinking sludge of Mayr-Melnhof Eerbeek – recycling paper mill
- Fine rejects from Smurfit Kappa Roermond Papier

Additionally the following materials are to be investigated:

- Pure cellulose from filter paper (ash less)
- End sludge from Municipal Wastewater Treatment (MWT) plant in Appeldorn

1.3.1 Investigated materials description

Secondary sludge was taken from sampling point in Industriewater Eerbeek after secondary clarifier and left in cylinder vessel to gravitational thickening reaching almost 10 % of consistency. Very high ash concentration is caused by nature of effluent treated in Industriewater Eerbeek. This wastewater treatment plant purifies outgoing wastewater from three different paper mills with different capacity and different raw material.

The excess of this sludge arising as a consequence of organic matter reduction in normally operating condition is mixed with primary sludge and subjected dewatering process.

Deinking sludge from Mayr-Melnhof Eerbeek was taken after dewatering unit and next suspension of 6% of it was prepared to experiments. It has also very high ash content reaching 75% of dry solids.

Fine rejects from Smurfit Kappa Roermond Papier origin from the last stage of stock cleaning before paper machine. They include up to 15 % of ash, 5% of fine plastic particles and mainly fibrous material.

Pure cellulose from laboratory filter paper as ash less was used to measure the potential of cellulose fibres. The suspension of 6% dry solid was prepared.

End sludge after anaerobic digestion from MWT origin from digestion of municipal sledges. (35% of ash content)

1.4 Partnership structure

KCPK – Kenniscentrum Papier en Karton - scientific organization for paper industry in Arhem, The Netherlands – Host organization

IPP – Institute of Papermaking and Printing at the TU in Lodz, Poland – home organization

IWE – Industriewater Eerbeek B.V. Industrial wastewater treatment – practical analysis, lab side, supervision.

1.5 Methodology

Practical research was performed with use of the following equipment

- Erlenmeyer's flask with gas production monitoring equipment.
- Thermostatic water bath
- Analytical apparatus

A volume of end sludge and suspension of each other material were mixed in plugged Erlenmeyer flask to total volume of 400 ml and connected to controlling gas production apparatus. To keep right temperature of process all of samples were submerged in thermostatic water bath at 37°C. The mixtures were not subjected to any continuously mechanical stirring except since time to time shaking around of each flask. Every day the amount of gas production were registered.

The experiment was ended after 13 days when gas production had been stopped or was less then few ml per day.

All of samples were analyzed before and after anaerobic digestion in order to determine:

- Dry solids content
- Ash content
- pH



Fig. 0 View on installation used in experiments

2 Results obtained in trials

2.1 Composition

In table below the composition of investigated mixtures (materials) are presented. All were calculated to DS in grams content in 400 ml mixtures before and after 13 days of anaerobic digestion. The results come from two trials that's why concentration of end sludge differ.

Sample of **end sludge** from MWT plant was used as a base of bacterial flora to create condition for initiation of anaerobic digestion because of it, in first sample only end sludge was used to have results as a blank sample so a 400 ml of end sludge was used.

To one of the sample with fine reject a dose of Viscostar 150L were added before digestion. The enzyme was chose from four others enzyme provided by Dyadic since processing condition of Viscostar 150L suite for pH range of the investigated mixtures.

Table 1 Composition of investigated mixtures

sample name	<i>Blank sample</i>	<i>Secondary sludge</i>	<i>Secondary sludge</i>	<i>Deinking sludge MM</i>	<i>Fine rejects SKRP</i>	<i>Fine rejects SKRP+enzyme Viscostar¹</i>	<i>Pure cellulose</i>
End sludge [ml]	400	300	200	300	200	200	300
Sample [ml]		100	200	100	200	200	100
End sludge concentration[%]	3,59	3,59	3,31	3,59	3,31	3,31	3,59
Sample concentration [%]	3,59	8,66	9,62	5,95	1,08	1,08	6
Mixture concentration before digestion [%]	3,59	4,9	6,46	4,19	2,2	2,20	4,2
Mixture concentration after digestion [%]	3,2	4,5	5,90	3,45	1,75	1,78	2,42
DS in mixture before [g]	14,36	19,48	25,86	14,36	8,80	8,80	16,84
DS in mixture after [g]	12,7	18,16	23,60	13,80	7	7,12	9,7
DS reduced [g]	1,64	1,32	2,26	2,96	1,80	1,68	7,16
Total gas production from mixture [ml]	529	541	530	617	354	502	3347
Gas prod. per gram of reduced matter	323	410	234	208	197	299	467
Percent of reduction in DS	11,4	6,8	8,7	20,6	20,4	19,1	42,5

¹ Viscostar 150L provided by Dyadic

2.2 Ash content

Only DS matter diminished by ash can be regarded as matter enable to decomposition.

In table below the percentage of ash content was presented. Ash content was measured in two temperatures 500°C and 900°C. Difference in value between them is caused mainly by chemical conversion of CaCO_3 into $\text{CaO} + \text{CO}_2$ at 900°C and can be used to calculate calcium carbonate amount in ash.

Tabele 2 Ash kontent in dry solids

sample name	Blank sample	Secondary sludge	Secondary sludge	Deinking sludge MM	Fine rejects SKRP	Fine rejects SKRP+enzyme Viscostar	Pure cellulose
Ash 500°C before digestion [%]	33,3	52,5	67,4	47,8	28,9	28,9	21,4
Ash 500°C after [%]	36,2	59,0	69,9	53,0	32,0	31,9	33,3
Ash 900°C after [%]	35,3	43,2	46,5	41,4	30,6	30,6	32,5

2.4 pH

All of the measured values were in neutral range 7,15-7,40 pH. And it assumed that it didn't have any bigger influence on obtained results.

2.5 Reduction of dry solids concentration

One of the major parameter in performed experiments was dry solids reduction Measured before and after digestion can indicate organic matter decomposition process efficiency.

The percentage of reduction was expressed as difference in concentration before and after and divided by initiate concentration. However this way of expressing efficiency makes very important to remember about ash content in every mixture because it is took into account what decrease the real decomposition rate of organic matter present in a sample.

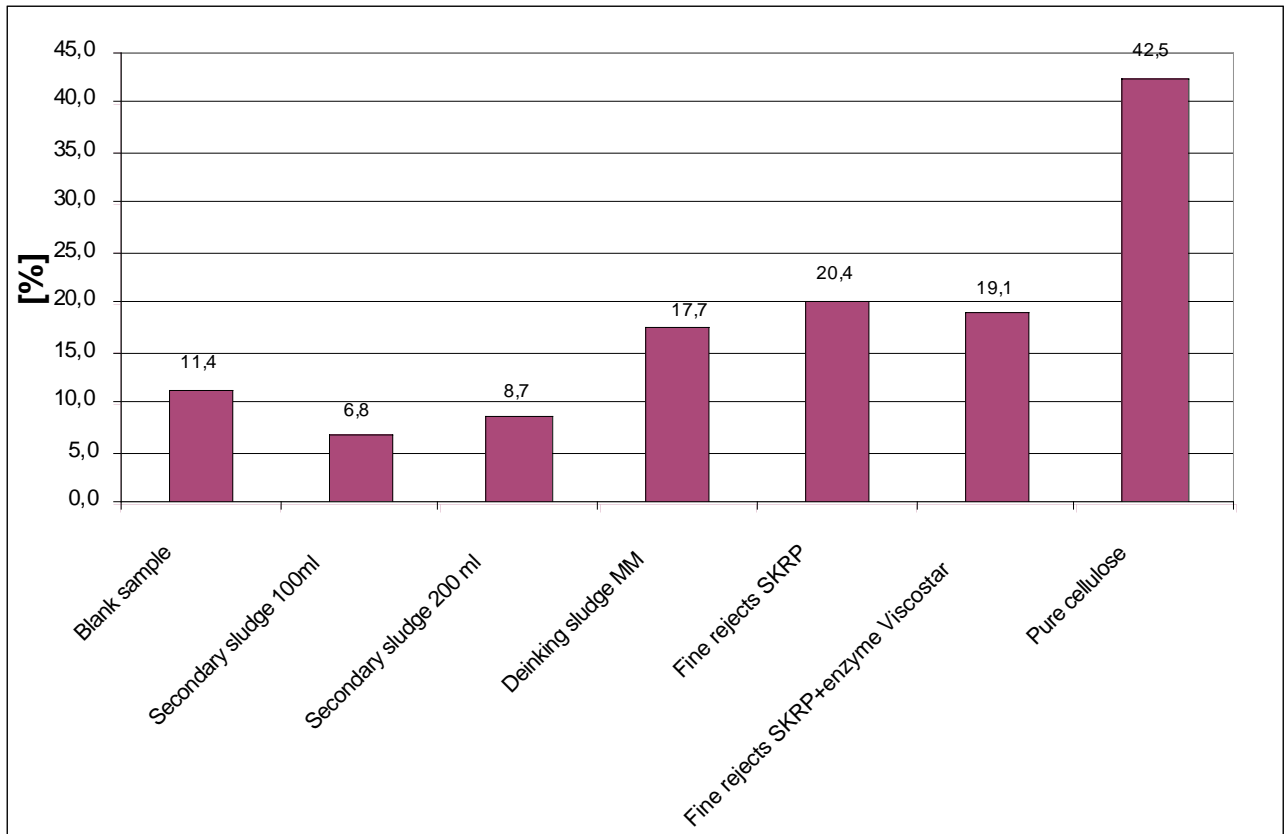


Fig. 1 Percentage of reduction of dry solids content during 13 days anaerobic digestion

- Cellulose high reduction rate shows the good digestibility of that matter what was expected
- Low level of reduction the samples with secondary sludge can be caused by the fact that is mainly biological sludge which is hardly to decompose in anaerobic digestion. However sample of secondary sludge of volume 200 ml instead of 100 ml in mixtures results as a 2% higher reduction in dry solids
- Fine rejects reduction lower with enzyme than without what request more investigation
- Almost 18 % reduction of deinking sludge from MM indicate on high share of fibres fines in raw deinking sludge used in trial which makes this material potentially good to use in digestion

2.6 Gas production

Total volumes gas production obtained from each of mixture are presented in table 1.

Efficiency of biogas production can be expressed as a gas production amount divided by difference between initial and final DS content. That kind comparison of digested material is presented below.

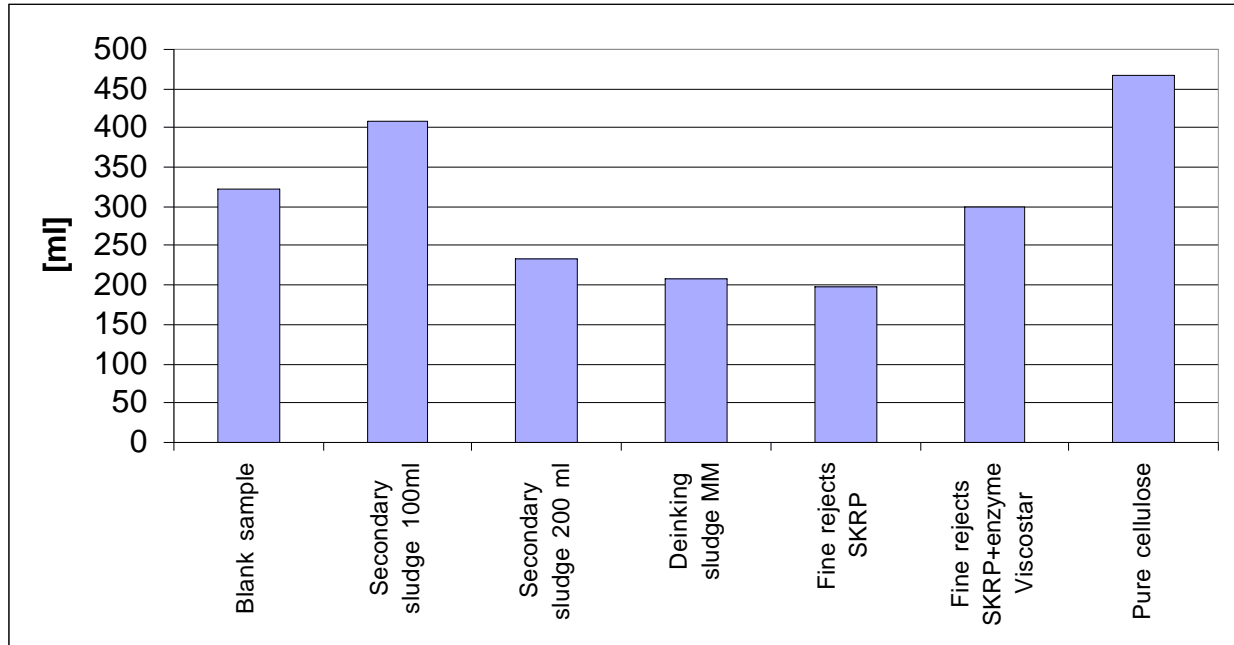


Fig. 2 Gas production amount per one gram of reduced matter [ml]

The highest rate of gas production characterizes mixture with cellulose sample.

Secondary sludge in volume 100 ml in mixtures produce also high amount of gas but the same material used in different proportion with end sludge (200 ml instead of 100 ml) gives lower efficiency of gas production.

The higher gas volume of sample fine reject with Viscostar enzyme can be caused by higher methane conversion rate than in sample without enzyme dose.

3 Conclusions

Further investigations are necessary in order to present the most objective and representative conclusions:

- to check the dosage of Viscostar 150L enzyme
- and other enzymes provided by Novozymes .
- Different proportion of mixtures also require investigation

These activities will clarify the real influence of certain enzymes on the bio-gas productivity efficiency of the so far analyzed materials. However it was not possible to perform overall activities in the first period of reporting within the STSM.

Energy and waste materials to be saved

In the recycling branch of paper industry 85 ktons of dry solid waste in form of coarse rejects is generated. This stream of materials has the potential of 2,1 PJ energetic value that could be obtained by incineration or gasification.

The cellulose fraction of the coarse rejects (if only separated) could be translated into 1PJ per year, the second main fraction, plastics could be than applied for recycling and/or energy recovery.

Next to coarse rejects, recycling branch of paper industry generates certain amounts of other waste streams in form of various cellulose (bio materials) containing fractions. Fermentation/bio gas production from those bio materials carry 1,4 PJ in theory. When those materials could be applied at the location of the paper mills equipped already with CHP plants, 7,5 million Euros could be saved (based on the current energy prices). What is more, the fermentation and bio-gas production are energy friendly technologies. Aforementioned aspects combine both, environmental and economical benefits.