



# Anaerobic digestion of fines from recovered paper processing – Influence of fiber source, lignin and ash content on biogas potential



Friedrich Steffen<sup>a</sup>, Ana Requejo<sup>b</sup>, Christian Ewald<sup>c</sup>, Ron Janzon<sup>a</sup>, Bodo Saake<sup>a,\*</sup>

<sup>a</sup>Chemical Wood Technology, Department of Wood Science, University of Hamburg, Leuschnerstr. 91B, 21031 Hamburg, Germany

<sup>b</sup>Chemical Engineering Department, University of Córdoba, Building Marie-Curie, Campus of Rabanales, 14071 Córdoba, Spain

<sup>c</sup>Department of Paper Technology and Mechanical Process Engineering, University of Darmstadt, Alexanderstr. 8, 64283 Darmstadt, Germany

## HIGHLIGHTS

- Fines fraction from recycled fiber had high ash and lignin content.
- Anaerobic digestion was not affected by inorganic compounds.
- Anaerobic conversion of carbohydrates was governed by substrate lignin content.
- Highest daily methane yield was obtained for fines from chemical pulps.
- Lignin-rich fines from mechanical pulps showed limited conversion rates.

## ARTICLE INFO

### Article history:

Received 27 July 2015

Received in revised form 23 September 2015

Accepted 1 October 2015

Available online 13 October 2015

### Keywords:

Biochemical methane potential (BMP)

Chemical pulp

Mechanical pulp

Recycled fiber

Fines

## ABSTRACT

Fines concentration harms paper machine runability and output quality in recovered paper processing, hence, their extraction would be fundamentally beneficial. In this study, separated fines from an industrial recycled fiber pulp (RFP) were characterized and evaluated for their potential biogas yields with a focus on understanding the role of varying lignin and ash contents. Further, these results were compared with biogas yields from conventional chemical and mechanical pulps. Overall, methane yields of fines from mechanical pulps (21–28 mL/g<sub>VS</sub>) and RFP (127 mL/g<sub>VS</sub>) are relatively low compared to the high methane yields of 375 mL/g<sub>VS</sub> from the chemical pulp fines. However, it was shown that the high ash content in RFP fines (up to 50%) did not negatively influence overall yield, rather, it was the presence of slowly biodegrading lignin-rich fiber fines.

© 2015 Elsevier Ltd. All rights reserved.

## 1. Introduction

The basic feedstocks of the paper industry are chemical and mechanical pulps. Chemical pulps are conventionally produced by combining wood chips and chemicals to break down the lignin while in mechanical pulping the wood chips are just ground up with refiner plates or grindstones. Mechanical pulps retain most of the natural lignin content whereas chemical pulps are widely delignified. However, today recovered paper has replaced virgin fibers from chemical and mechanical pulps as the most important fiber resource for the European paper and board industry. In the European Union in 2014, approximately 47.5 million tons of paper was recycled. With total paper and board production reaching

around 91 million tons (CEPI, 2015) this results in a utilization rate of 52%.

This trend has been driven by lower energy and water consumption in stock preparation, lower purchase cost, preservation of valuable wood resources and reduction of CO<sub>2</sub> emissions through usage of recovered paper.

Recovered paper however requires pretreatment before being suitable for producing new paper. Specifically, ink, organic and inorganic fillers, adhesives (“stickies”), plastic and metal impurities negatively impact product quality and production processes, hence, require prior removal. Depending on the recovered paper grade, several processing stages are employed with up to 25% of the raw materials ending up as process rejects as described by Mäkinen et al. (2013).

Today, stock preparation plants overwhelmingly aim for minimal removal percentages to gain maximum paper yields, whilst willingly retaining some impurities and accepting the

\* Corresponding author. Tel.: +49 4073962510; fax: +49 4073962599.

E-mail address: [bodo.saake@uni-hamburg.de](mailto:bodo.saake@uni-hamburg.de) (B. Saake).

forementioned problematic consequences. It is no surprise that organic and especially inorganic fine particles in recovered paper, hence, are approaching or even exceeding problematic concentrations (Hirsch et al., 2011; Rao et al., 2011). Producers of packaging paper are most affected and now are facing significant challenges in strength properties and the dewatering ability of the paper web (Hirsch et al., 2008; Olejnik et al., 2012) though other areas of the industry are facing similar difficulties.

A full selective removal of organic and inorganic fine particles would be desirable; yet, common separation techniques such as flotation cells, screens and hydrocyclones currently cannot separate these fractions under satisfactory technical and commercial considerations (Hirsch et al., 2010).

However, shifting the perception of fines from being a waste product towards becoming an input for an entirely different high value production process (like biogas production), could significantly strengthen the case for increased fines removal. The final report of COST action E48 (Stawicki and Read, 2010) describes such shift from a “yield-maximizing-strategy” towards a more holistic view in more detail, an approach described as the “recycled fiber biorefinery”.

Fines are also present in other reject streams from recovered paper processing. The deinking of recovered paper, for instance, generates large amounts of sludge which has to be extensively treated before disposal. In Germany alone, the amount of deinking sludge in 2013 was around 960,000 tons (Jung et al., 2014). Understandably, there is great interest from deinked pulp mills to reduce the amount of waste and improve raw material efficiency.

Anaerobic digestion (AD) of removed fines hereby could be attractive with AD already having a long successful history in various other domains including recent expansions to cover agro-waste, manure or even energy crops as input (Sawatdeenarunat et al., 2015).

The commercial case for on-site AD is based on the reduced transportation costs for removed solids, the generation of direct revenues from the actual biogas production as well as the additional possibility of utilizing the surplus heat.

Pulp and paper sludge has recently been analyzed in this context (Lin et al., 2011; Bayr and Rintala, 2012; Hagelqvist, 2013), yet to the authors' knowledge no information is available specifically regarding AD of separated fines fractions from recovered paper processing.

The composition of recovered paper is very heterogeneous due to the many different raw materials used including various chemical or mechanical pulps as well as various additives found like coatings and printing inks. Therefore, to gain a better understanding, conventional chemical and mechanical pulps were chosen as benchmarks for methane production. These results were then compared with the yields achieved through the digestion of recycled fiber fractions to better understand the potential for these different input streams for AD as well as specifically the respective role played by lignin, carbohydrates and inorganic component concentration of substrate on overall methane yields.

## 2. Methods

### 2.1. Raw material

Chemical and mechanical softwood pulps as well as an industrial recycled fiber pulp were selected for characterization and biochemical methane potential (BMP) tests in this study, namely:

- (1) Bleached kraft pulp from Zellstoff Stendal in Arneburg, Germany.
- (2) Bleached sulfite pulp from SCA Hygiene Products in Mannheim, Germany.

- (3) Bleached thermomechanical pulp (TMP) from UPM in Schongau, Germany.
- (4) Bleached stone groundwood pulp (SGW) from UPM in Augsburg, Germany.
- (5) Recycled fiber pulp (RFP) from Weig-Karton in Mayen, Germany.
- (6) Unbleached kraft pulps, produced in laboratory-scale pulping.

For compositional analysis, chemical and mechanical pulp samples were air-dried at room temperature, whereas the recycled fiber pulp samples were freeze-dried at  $-85\text{ }^{\circ}\text{C}$  and 1 mbar. Before each analytical treatment, the total solids (TS) content of the samples was determined gravimetrically.

### 2.2. Pretreatment

#### 2.2.1. Pulping

Kraft pulping was performed in a 7 L-laboratory digester from M/K systems with 700 g oven dry (o.d.) spruce wood chips. Liquor to wood ratio was 4:1 with an active alkali charge of 24% (as NaOH) and 30% sulfidity. The cooking temperature ( $T_{\text{max}}$ ) was  $165\text{ }^{\circ}\text{C}$  and heating-up time was 90 min. To gain pulps with different degrees of delignification, the cooks were stopped after 10, 30 and 50 min at  $T_{\text{max}}$  as well as directly after heating-up. After cooking, the wood chips were discharged in a washing screen, washed thoroughly with tap water, defibered in a laboratory pulper and then screened on a 0.15 mm laboratory slot screen to determine the yield of accepted pulp and rejects. The screened pulps were dewatered and stored in polyethylene bags at  $4\text{ }^{\circ}\text{C}$  until further processing.

#### 2.2.2. Refining and screening

To obtain sufficient fines material for the experiments, the chemical pulps were treated in a Voith laboratory refiner at 4% consistency for 20 min. From each pulp (kraft and sulfite) 1.7 kg o.d. material was used for refining. The specific refining energy was 250 kWh/t for the kraft pulp and 200 kWh/t for the sulfite pulp, resulting in beating degrees of 54°SR (kraft) and 62°SR (sulfite).

From all four original pulp samples and the recycled fiber pulp, fines fractions were obtained after screening in a pressure screen with a 150  $\mu\text{m}$  hole basket. Between 725 and 860 g of o.d. material were used for screening. The pulp consistency during screening was kept at 1% and the accept/reject rate was 50%. The flow-rate was 200 L/min. After screening, the separated fines fractions were dewatered to a consistency of around 38%, using 0.1% cationic retention agent (based on dry matter).

#### 2.2.3. Dispersion and flotation of RFP fines

The separated fines fraction from the recycled fiber pulp was dispersed for 10 min at room temperature in a laboratory mixer. Afterwards, around 192 g o.d. of this suspension was diluted with  $45\text{ }^{\circ}\text{C}$  warm water to a consistency of 0.9%. Based on dry matter, 0.3% sodium hydroxide and 1.2% oleic acid were added and flotation was conducted in a Voith Delta 25 laboratory flotation cell for 5 and 60 min. Air supply was set to 7.4 L/min.

### 2.3. Raw material characterization

Carbohydrate and lignin contents were analyzed by a two-stage acid hydrolysis. 200 mg of o.d. material were hydrolyzed with 2 mL of 72% sulfuric acid at  $30\text{ }^{\circ}\text{C}$  for exactly one hour to break up the crystalline structure of the cellulose. Thereafter, the sulfuric acid was diluted by adding 56 mL of water and then the samples were put in an autoclave at  $120\text{ }^{\circ}\text{C}$  and 1.2 bar for 40 min to degrade the

Download English Version:

<https://daneshyari.com/en/article/7072697>

Download Persian Version:

<https://daneshyari.com/article/7072697>

[Daneshyari.com](https://daneshyari.com)