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Mechanical pre-treatment of source-collected municipal biowaste prior to energy recovery by anaerobic digestion

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1 **Mechanical pre-treatment of source-collected municipal biowaste prior to energy**
2 **recovery by anaerobic digestion**

3

4 **Abstract**

5 Pre-treatments are usually necessary to prepare biowaste to anaerobic digestion. The major
6 objectives are (i) to remove undesirable materials such as plastics and metals, which may
7 contaminate the biowaste even if separated source-collection systems are implemented, and (ii)
8 to extract the most readily biodegradable organic fractions from the waste stream. In this study,
9 two wet mechanical pre-treatments, namely air-compressed press and worm screw press, were
10 investigated on urban household biowaste. Two liquid to solid ratios were tested in each pre-
11 treatment. Anaerobic digestion of pre-treated biowaste was studied by measuring their
12 biomethane potentials and by controlled experiments in a continuously stirred-tank reactor with
13 a feed load of $3.5 \text{ gVS.L}^{-1}.\text{d}^{-1}$. It was observed that increasing liquid to solid ratio in the pre-
14 treatments allowed to increase the proportion of biodegradable organic matter extracted from
15 the biowaste, up to $949 \text{ gCOD.kgTS}^{-1}$ from household biowaste. The biomethane potentials of
16 pre-treated waste were very high (up $525 \text{ LCH}_4.\text{kgVS}^{-1}$) and COD ($949 \text{ gCOD.kg}^{-1}\text{TS}$) from
17 household biowaste. Anaerobic digestion in continuously stirred-tank reactor showed a very
18 strong conversion of COD load (81%) and a high methane production up to $345 \text{ LCH}_4.\text{kgVS}^{-1}$.

19

20 **Keywords:** pre-treatment, press, anaerobic digestion, biowaste, biomethane potential.

21

22 **Abbreviations**

23 ASF - Aqueous Slurry Fraction

24 BMP- Biochemical Methane Potential

25 GC-TCD - Gas Chromatography equipped with a Thermal Conductivity Detector

- 26 COD - Chemical Oxygen Demand
- 27 CSTR - Continuous Stirred-Tank Reactor
- 28 HBW- Household Biowaste
- 29 MSW - Municipal Solid Waste
- 30 NH₄-N - ammonia nitrogen
- 31 OLR - Organic Loading Rates
- 32 PT#1 - Pre-treatments with air-compressed press
- 33 PT#2 - Pre-treatments with worm screw press
- 34 SF- Solid Fraction
- 35 SBW - Biowaste from Supermarkets
- 36 TKN - Total Kjeldahl Nitrogen
- 37 TS - Total Solids
- 38 VFA - Volatile Fatty Acids
- 39 VS - Volatile Solids
- 40 WSC - Water Soluble Carbohydrates

41

42 **1 Introduction**

43 Over the last decade, European and French legislations on waste management have
44 been strongly pushing the prevention of waste production and the recovery of materials and /or
45 energy from the waste stream, with a strong incentive to reduce drastically landfill disposal.
46 The European Directive 2018/851/EC encourages European Union member states to implement
47 systems for the specific collection of source-separated biowaste to facilitate the recovery of
48 organic matter (European Union, 2018). In France, the energy transition for green growth act
49 requires that municipalities take proper measures to achieve before 2025 specific collection and

50 resource recovery targets from municipal biowaste streams (LTECV, 2015). Despite the efforts
51 to prevent waste generation, Municipal Solid Waste (MSW) production is still growing in most
52 cities, following the growth of the population in urban areas (Fisgativa et al., 2016, Jank et al.,
53 2017). MSW includes several categories of waste collected on the urban territories, including
54 biowaste. Municipal biowaste consists of gardens and parks waste, food and kitchen waste from
55 households, offices, restaurants, wholesalers, canteens, catering and retail units, and similar
56 waste from food processing industry (European Union, 2018). Household waste represents the
57 main category of biowaste, corresponding to more than 34% of the mass of MSW generated in
58 Europe in 2017 (European Environmental Agency, 2020).

59 Among the processes available to recover materials and/or energy from biowaste,
60 anaerobic digestion appears as a very attractive solution (Shahriari et al., 2012; Cesaro and
61 Belgiorno, 2014). It has a low production of biosolids, low energy consumption, and high rates
62 of methane production. Anaerobic digestion of biowaste is also considered a good solution to
63 reduce landfill disposal while producing a renewable energy vector and an organic fertilizer
64 (Novarino and Zanetti, 2012; Fisgativa et al., 2016).

65 The efficiency of anaerobic digestion depends, however, on the composition and
66 characteristics of biowaste, since biochemical constituents are more biodegradable into
67 methane than others (Bayard et al., 2016, Komilis et al., 2017). In most cities around the world,
68 biowaste streams are currently collecting mixed with other non-biodegradable materials such
69 as plastics, inorganic components, and ligno-cellulosic fractions which are rather recalcitrant
70 (Saint-Joly et al., 2000; Fisgativa et al., 2017). The presence of these impurities in biowaste can
71 cause technical problems in the anaerobic digestion process and depreciate the quality of the
72 biogas and/or the residual digestate, which can lead to environmental impacts (Hartmann et al.,
73 2004, Naroznova et al., 2016). Therefore, most of the organic waste substrates need to be pre-
74 treated mechanically to remove impurities and make biodegradable matter more easily available
75 (Jank et al., 2017, Lopes et al., 2019).

76 In a previous study, press separation was shown to generate a readily biodegradable
77 aqueous slurry with a high biomethane potential (Micolucci et al. 2015, Lopes et al. 2019).
78 Thus, higher values of biogas production rate in the aqueous slurry fraction are expected when
79 compared to the particulate fraction due to a significantly higher content of ligno-cellulosic
80 fibres and lower biodegradability (Hansen et al., 2007, Jank et al., 2015). The distribution of
81 the waste between the two output fractions from the press process is affected by the pressure
82 (Moretti et al., 2020, Moretti et al., 2021). Many works used press technologies to study specific
83 fractions of interest in the anaerobic digestion process (Nayono et al., 2010a, Micolucci et al.,
84 2015, Micolucci et al., 2016, Lopes et al., 2019).

85 The objective of this work was to determine the conditions, in relation to dry matter
86 content in the aqueous slurry fraction (ASF) as well as the percentage of dry matter extracted
87 into this fraction, from the initial samples of biowaste. Two experimental devices of mechanical
88 pressing, namely air-compressed press (PT#1) and worm screw press (PT#2), were compared.
89 These two technologies were chosen because of their set up facilities and efficiency already
90 proven in the literature. In a first step, two conditions of liquid/solid ratio were compared for
91 the extraction of ASF from household biowaste samples (HBW). In a second step, the anaerobic
92 digestion of a mixture of HBW ASF with a pulp extracted from supermarkets biowaste (SBW)
93 samples was studied in a continuously stirred-tank reactor (CSTR), to assess the performance
94 of methane production in dynamic conditions of treatment.

95

96 **2 Material and Methods**

97 The flowchart of the successive operations implemented on the biowaste samples is
98 shown in Fig. 1.

99

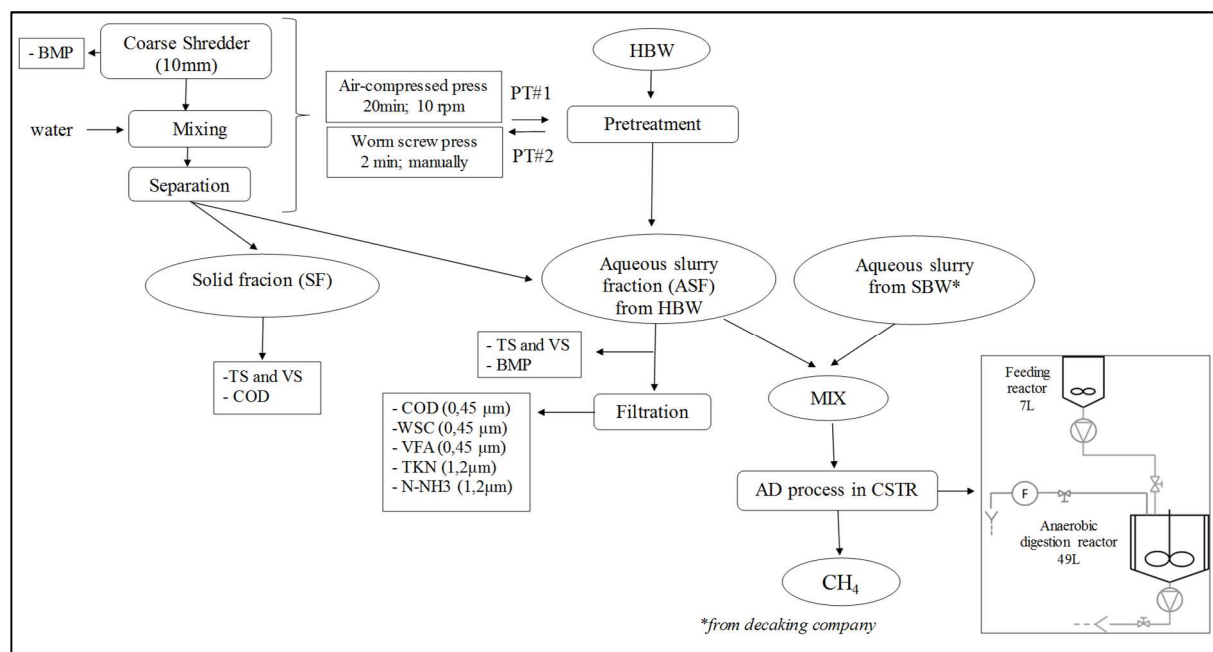


Fig. 1. Flowchart of global scheme of pre-treatment and anaerobic digestion process

2.1 HBW pre-treatment

2.1.1 Pre-treatment procedures

Two pre-treatments technologies on HBW collected at source from a selective collection were studied, namely: air compressed press (PT#1) and worm screw press (PT#2). The experimental procedure shown in Fig. 1 was designed to extract as much as possible the soluble and colloidal organic matter from the biowaste in ASF (Moretti et al., 2020). The first operation of shredding was done to homogenize the samples in order to ensure the reproducibility and relevance of the results obtained. Each shredded sample was then soaked in de-ionized water. Two different liquid to solid ratios (L/S), 5 and 10 g of water per g of biowaste (dry mass), were tested. Then, liquid/solid separations were performed.

2.1.2 Air compressed press pre-treatment of HBW (PT#1)

Filtration-compression cells were used to produce ASF. Experiments were carried out in triplicates, using identical cylindrical stainless-steel cells of 0.46 L and 70 mm inner diameter.

117 The lower part of the cylinder cells was composed of a perforated stainless-steel disc with 3
118 mm diameter holes. This technology allowed to work at high controlled pressure (up to 10 bars)
119 but with a small load of biowaste. The biowaste suspension obtained after soaking was
120 introduced into the cylinder cells and pressing 20 minutes at 6 bars.

121 Following the pressing operation, the ASF was collected from the bottom and the solid
122 fraction (SF) part on the filter was removed from the cylinder cells.

123

124 *2.1.3 Worm screw press pre-treatment of HBW (PT#2)*

125 The biowaste suspension obtained after soaking in water was introduced into the worm
126 screw press developed by the company Altantique industrie[®] to separate the liquid phase from
127 the solid phase by the principle of separation by gravity and mechanical pressing. HBW were
128 added at the feed inlet located at the beginning of the auger. The biowaste was carried by the
129 auger to the outlet. Located at the outlet, a cork valve equipped with a hydraulic cylinder
130 allowed compressing the biowaste as the material was added to the inlet. Under the pressure
131 effect, the valve opened, allowing the exit of the solid material, constituting the remained SF.
132 The pulp, resulting from the pressing, was collected through a cylindrical grid (2 mm diameter
133 perforations) located along the entire length of the pressing chamber. Finally, with the use of a
134 recovery tank, the ASF was collected at the level of the liquid outlet.

135 This technology has a high loading capacity with a batch of 50 L of soaked biowaste. A
136 quantity of biowaste was set in the container, water was added to reach 25 kg of biowaste
137 suspension, and then was mixed manually with a shovel for 2 min.

138

139 *2.1.4 Physico-chemical analyses of the ASF*

140 ASF obtained from HBW mechanical pre-treatments was analysed in triplicates. The total
141 solid (TS) and volatile solid (VS) contents for all samples were determined through 105°C
142 drying for 24h and calcination at 550°C during 2h (APHA, 2012). For mass balance, SF after

143 press was characterized, the samples were dried at 70 °C until constant weight (3 days) and
144 crushed down to below 2 mm. Chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN),
145 and ammonia nitrogen (NH₄-N) were analysed according to standard methods (Baird and
146 Bridgewater 2017).

147 Volatile fatty acids (VFA) were measured by gas chromatography (Shimadzu Corp.)
148 equipped with a HP-FFAP fused silica capillary column (30 m×0.25 mm Agilent
149 Technologies), using H₂ as carrier gas and a flame ionization detector. Lactic acid, formic acid,
150 and water soluble carbohydrates (WSC) were analysed by liquid chromatography (LC Module
151 1 plus, Waters), equipped with a Supelcogel™ C-610 column (300 mm×7.8 mm, Sigma-
152 Aldrich) with 0.1%v H₃PO₄ solvent (flow rate of 0.5 mL.min⁻¹). All liquid samples were filtered
153 at 0.45 µm before analyses. All the analyses were performed in triplicates.

154

155 *2.1.5 Biochemical methane potentials (BMP) analyses of ASF*

156 The BMP test was carried out following the guidelines reported by Holliger et al. (2016)
157 thermostatically controlled at 35 °C. The BMP was performed on raw HBW, ASF, and ASF
158 mix, destined for treatment in the reactor. For raw biowaste samples, 2 L glass vessels were
159 used to guarantee the representativeness of the samples. For the ASF, 0.5 L glass vessels were
160 used. The digested sludge from wastewater treatment plant in Lyon, France, was used as an
161 inoculum, presenting TS 2.0-3.3%wt and VS 1.4-2.2%wt. The glass vessels were filled with
162 the samples and inoculum, in the proportion of 2 g.g⁻¹. Subsequently, the glass vessels were
163 purged with N₂/CO₂ (80/20% v/v) gas for about 2 minutes, sealed, and equilibrated at 35 °C. In
164 addition, blanks composed of only inoculum and distilled water measured. This aimed to correct
165 the recorded BMP from inoculum's residual methane production, and a positive which has
166 already known BMPs for the validation of BMP test results. All the analyses were made in
167 triplicates.

168 Biogas production was measured by monitoring the pressure in the flasks using a Digitron
169 precision manometer. The gas composition was analysed using an Agilent 3000 micro gas
170 chromatography equipped with a thermal conductivity detector (GC-TCD). Molsieve 5A (14 m
171 length; pore size: 5 Å) and PoraPlot A (10 m length, 0.320 mm ID) columns were used as
172 stationary phases for GC-TCD, using argon as a carrier gas. The tests were stopped when the
173 biogas production in one day was less than 1% of the total volume of biogas produced (Holliger
174 et al., 2016). The rate of methane production was determined from the net methane production
175 and was used a first order kinetic model, as presented in Eq.1.

176

$$177 \quad V_{CH_4}(t) = V_{max}(1 - e^{-kt}) \quad (1)$$

178

179 Where: V_{CH_4} is the volume of methane produced at time t , in NL; t is the time, in days; V_{max} is
180 the maximum volume of methane produced, in NL; and k is the first order kinetic constant.

181

182 *2.1.6 Balance of TS, VS and COD between ASF and remaining SF*

183 Mass balance calculations were performed on the biowaste before treatment and on the
184 ASF and SF obtained after separation. The content of TS, VS, and COD were analysed. The
185 mass balance between the ASF and SF, of each respective biowaste sample, were calculated
186 using the Eq.2 where i was defined as the proportions of TS, VS, and COD, and x corresponds
187 the ASF and PF. It was expressed in % w/w.

188

$$189 \quad y_{i,x} = \frac{m_{i,x}}{m_{i,ASF} + m_{i,SF}} \cdot 100 \quad (2)$$

190

191 **2.2 Treatment of aqueous slurry mix by continuous anaerobic digestion process**

192 *2.2.1. Feedstock of aqueous slurry for anaerobic digestion: ASF mix.*

193 Anaerobic digestion assays were performed with a mix of aqueous slurry from HBW and
194 SBW stream. HBW aqueous slurry was obtained from the worm screw press system PT#2 (see
195 section 2.1.3). SBW pulp was collected from the company ECOVALIM dealing with the
196 depackaging of mixed supermarket food waste in Rhône area (France). ASF mix was performed
197 with 65% of HBW aqueous slurry and 35% of SBW aqueous slurry in humid mass. The choice
198 of mixing HBW and SBW in that proportion was made considering the profile of production of
199 biowastes of Grand Lyon urban territory: HBW and SBW were the main biowaste streams on
200 territories, with green biowaste coming after, but this last being interesting for anaerobic
201 digestion because of its high lignocellulosic contents (Moretti et al., 2020). The feedstock was
202 packed in 2 L container and then freeze at -20 °C waiting for reactor feed.

203

204 *2.2.2. Anaerobic digestion process and operational condition*

205 Anaerobic digestion process was performed in 49 L hermetic CSTR, mixed and
206 thermostated at 35 °C. Fig. 1 illustrates the anaerobic digestion set up. Feedstock of ASF mix
207 was introduced by feeding the digester of 7 L. Pump fed the anaerobic reactor each day at 0.10
208 L.min⁻¹ during a feeding time depending on organic loading rate (OLR) (except weekend).
209 Extraction was performed simultaneously to feeding to ensure constant reactor volume and
210 continuous mode. Biogas output was on the top of the anaerobic reactor and a mass flowmeter
211 recorded continuously biogas flow.

212 In the literature, OLR ranking is reported between 2 to 10 gVS.L⁻¹.d⁻¹ with a hydraulic
213 retention time up to 20 days (Nayono et al., 2010b, Micolucci et al., 2016, Komilis et al., 2017,
214 Malinowsky et al., 2021). Considering these previous works, operational conditions were an
215 OLR of 3.5 gVS.L⁻¹.d⁻¹ associated with a hydraulic retention time of 38.6 days. Results herein
216 presented were obtained during stabilized conditions of the process. The inoculum used for the
217 mesophilic trials was digested sludge from the full-scale anaerobic digestion process of
218 wastewater treatment plant, in Lyon, France. The pilot was maintained at an operating

219 temperature of 35 °C with OLR for two weeks to acclimatize the biomass to ASF mix. Once
 220 the biomass was stabilized, the reactor was fed daily.

221

222 2.2.3. Reactor monitoring

223 The reactor was monitored to ensure correct digestion conditions and to determine reactor
 224 efficiencies. Analysis methods are presented in section 2.1.4. TS, VS, COD soluble, and VFA
 225 were determined three times a week on input and digestat. COD_{total}, TKN, and WSC were
 226 measured once a week. Biogas composition was also followed, with three samples a week
 227 analysed by GC-TCD analysis. The pH, temperature, and gas flow were monitored by online
 228 sensor measures connected to acquisition software.

229

230 3 Results and Discussion

231 3.1 Extraction of digestible matter from HBW using different press systems

232 Table 1 shows the TS and VS content for HBW pressed processed by the air-compressed
 233 press (PT#1), or processed by the worm screw press (PT#2). For PT#1 system, two pulping L/S
 234 ratios were tested to obtain a dry matter content of the ASF suitable for the anaerobic digestion
 235 (between 4 and 10% of TS).

236

237 **Table 1.** TS and VS contents of aqueous slurry fraction (ASF) obtained from household
 238 biowaste (HBW) pressed with air-compressed press PT#1 and pressed with worm screw press
 239 PT#2. Results are expressed in % of the dry mass of the respective fraction

ASF	PT#1: HBW pressed with air-compressed Press		PT#2: HBW pressed with worm screw press	
	L/S 5	L/S 10	L/S 5	L/S 10
TS	7 ± 0.4%	5 ± 0.4%	8 ± 0.0%	4 ± 0.0%
VS	79 ± 1.0%	84 ± 1.0%	86 ± 0.0%	87 ± 1.0%

240

241 Increasing the L/S ratio decreased TS content in the ASF, for both press technologies.
242 Few variations in VS concentration were observed. When analysing the performance of the two
243 mechanical pre-treatments, it was observed that, comparing the same ratio in both pre-
244 treatments, the TS values were similar. The VS values from worm screw press PT#2 were
245 slightly higher than those found from air-compressed press (PT#1) (Table 1).

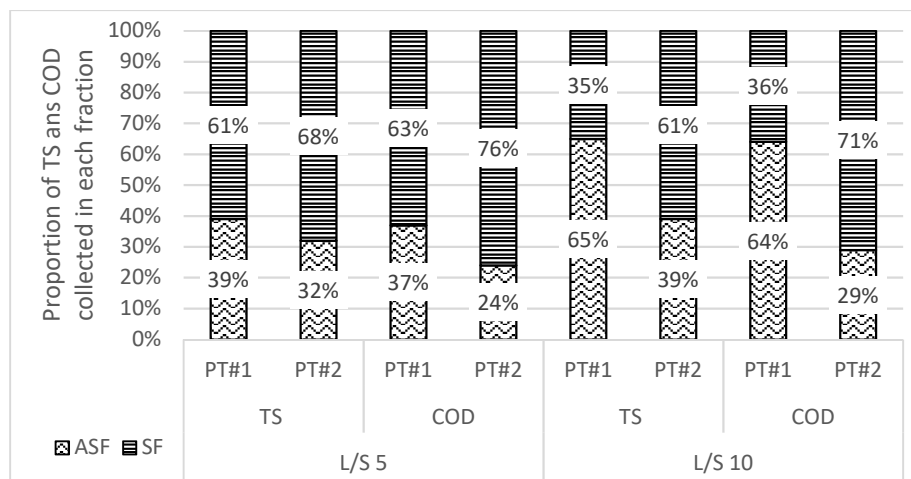
246 A wide range of TS value of ASF was found in literature, ranging from 10 to 42% (Hansen
247 et al., 2007, Bernstad et al., 2013, Jank et al. 2015, Micolucci et al., 2015, Lopes et al., 2019).
248 Similarly, Lopes et al. (2019) analysed, among other processes, the pressing of the mixture of
249 food and garden waste from households with water (ratio of approximately 350 kg of water per
250 1000 kg of biowaste) and obtained a value of 27.5% of TS for the aqueous fraction resulting
251 from pressing. The highest TS value reported in the literature mentioned in this paragraph, when
252 compared to the result of the present study, could be related to a higher cut-off point of the press
253 of 12 mm compared to 3 and 2 mm in our case. This could mean that the cut-off point is a
254 crucial parameter to promote TS concentration in ASF.

255 Fig. 2 presents the distribution of mass between ASF and SF, after the pre-treatment
256 process for HBW in the two pre-treatments technologies at different L/S ratios.

257 TS initially present in the biowaste and water mixture was collected mostly in SF. With
258 the water addition, *i.e.*, increasing the L/S ratio, the reduction on the proportion of the TS into
259 SF was observed, and consequently an increase in the ASF, demonstrating a positive influence
260 on TS extraction in this fraction. It has been observed that 32% of TS was extracted in liquid at
261 L/S ratio of 5, while this proportion increased to 39% at L/S ratio of 10, for the worm screw
262 press PT#2. The same phenomenon was also noted with air-compressed press PT #1 (39% to
263 65%). These values are similar to those observed in the work by Hansen et al. (2007) that found
264 the TS values between 23% w/w and 28% w/w into the biomass fraction (soft and wet waste,
265 mainly organic waste) with the screw press from households waste. Micolucci et al. (2015)

266 found a slightly lower value, about 18% of TS, in wet fraction from a pilot scale press to pre-
 267 treat collected biowaste. However, pressure values were not reported in these studies.

268



269

270 **Fig. 2.** Evolution of mass fraction of TS and COD at different L/S ratio: 5 and 10 gWater.gTS⁻¹
 271 ¹ of HBW pressed with air-compressed press (PT#1) and HBW pressed worm screw press
 272 (PT#2)

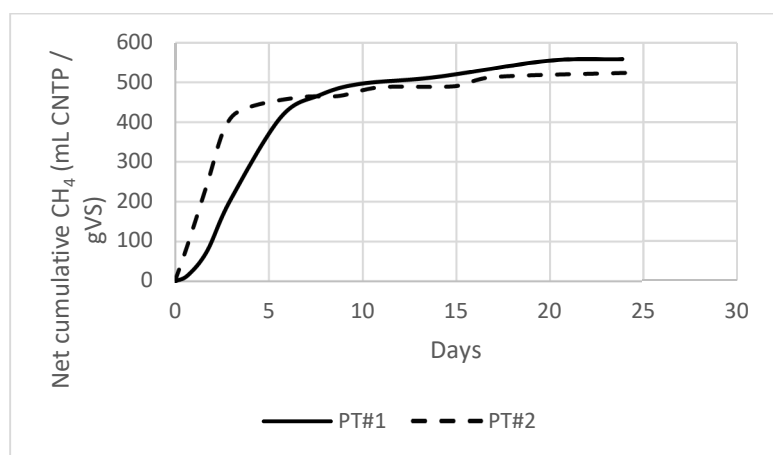
273

274 Similar behaviour was observed in the proportion of COD in the ASF. In both pre-
 275 treatments, there was an increase in the proportion of COD in the ASF due to the increase in
 276 the L/S ratio, from 37% to 64% for the PT#1 system and from 21% to 29% for the PT#2 system.
 277 These facts could be explained by the higher extraction of particulate matter from ASF due to
 278 the increase in the amount of free water. TS and VS results showed that water addition before
 279 mixing decreases TS concentration of ASF but increases the total fraction of extracted TS.

280 According to the data discussed, as well as can be seen in Fig. 2, worm screw press process
 281 PT#2 was less efficient than air compressed press PT#1 on TS and COD extraction, since PT#1
 282 system was able to extract a higher percentage of these parameters in the ASF, by increasing
 283 the L/S ratio with the addition of water. It could be explained by higher pressure extraction in
 284 this pre-treatment process, about 6 bars, that involve higher strength to extract valuable matter
 285 in ASF.

286 Fig. 3 presents cumulative production of methane during BMP test for ASF from air-
 287 compressed press PT#1 and worm screw press PT#2. Methane production from the ASF from
 288 HBW processing with PT#1 system ($523.8 \text{ NLCH}_4.\text{kgVS}^{-1}$) and PT#2 system
 289 ($524.8 \text{ NLCH}_4.\text{kgVS}^{-1}$) obtained was similar. However, the kinetic constants were higher in
 290 ASF from worm screw press PT#2 ($0.57.\text{d}^{-1}$) when compared to ASF from air-compressed press
 291 PT#1 ($0.29.\text{d}^{-1}$). These results suggest less readily bioavailable compounds in the last fraction.
 292 The values obtained are similar to those obtained by Alessi et al. (2020) of $536 \text{ NLCH}_4.\text{kgVS}^{-1}$
 293 ¹ and slightly above those found in other studies: 360 to $460 \text{ NLCH}_4.\text{kgVS}^{-1}$ (Hansen et al.,
 294 2007; Jank, et al., 2015; Fisgativa et al., 2016).

295



296

297 **Fig. 3.** Evolution of net cumulative biomethane production through BMP test of ASF after PT#1
 298 (air compressed press) and PT#2 (worm screw press) at L/S 5 ratio. Meaning of triplicated
 299 assays

300

301 In order to feed the anaerobic digestion process to the next step, the choice of HBW pre-
 302 treated was done considering the TS and VS contents present in ASF, the proportion of TS and
 303 COD extract in ASF, the BMP production, and other variables, like the capability to produce
 304 large quantity ASF and consume of water and air-compressed. Despite the higher values of TS
 305 and COD extraction in the ASF in air compressed press PT#1 at the L/S ratio 10, in order to

306 feed the anaerobic digestion process, the worm screw press pre-treatment PT#2 at L/S of 5
 307 gWater.gTS^{-1} was chosen. The L/S 5 ratio was selected because of the interesting TS
 308 concentration (8%) of ASF produced, with high BMP while minimizing water addition during
 309 pre-treatment. Worm screw press PT#2 was preferred than air-compressed PT#1 because of its
 310 capability to produce more quantity of ASF, higher kinetic constants, and no need of
 311 compressed air. Table 2 presents characterization of ASF from HBW destined for anaerobic
 312 digestion after PT#2 system.

313

314 **Table 2.** Bio-chemical characterization of aqueous slurry fraction (ASF) from household
 315 biowaste (HBW), supermarket biowaste (SBW) and feeding mix (ASF Mix)

Parameter	Unit	HBW ASF	SBW ASF	ASF Mix 65% HBW 35% SBW
pH	-	4.7	4.3	4.4
N-NH ₃	mgN.L ⁻¹	384.0 ± 38	594.0 ± 55	430.0 ± 41
N-TKN	mgN.kgTS ⁻¹	33.1 ± 4	22.9 ± 11	26.0 ± 2.0
COD	gCOD.kgTS ⁻¹	949.0 ± 48	1064.0 ± 22	1025.0 ± 41
VFA	equivalent gCOD.L ⁻¹	45.0 ± 5	43.4 ± 4	38.7 ± 5.0
WSC	equivalent gCOD.L ⁻¹	0.6 ± 0.01	2.2 ± 0.3	1.4 ± 0.2
BMP	LCH ₄ .kgVS ⁻¹	525.0 ± 13	300.0*	340.0 ± 8.5

316 * BMP calculated from BMP of HBW and ASF, considering VS of each fraction in the Mix.

317

318 **3.2 Treatment of ASF mix by anaerobic digestion in a reactor**

319 **3.2.1 ASF mix composition: ASF of HBW and SBW**

320 ASF mix was produced using HBW and SBW aqueous slurry from mechanical pre-
 321 treatment (see section 2.2.1). The results from the chemical analyses of ASF from HBW, SBW,
 322 and ASF mix are presented in Table 2.

323 HBW and SBW showed similar concentrations of NTK and COD, however, the presence
 324 of N-NH₄ and WSC was much higher in SBW. This suggests that SBW stream was charged in
 325 sugar food and proteins highly available. The ASF mix is highly concentrated in COD with a

326 COD/N ratio around 39 gCOD.gN⁻¹. A high proportion of VFA has been observed, representing
327 39 gCOD.L⁻¹, principally lactic acid, which indicated that acidogenesis was currently
328 beginning. The ASF mix is highly biodegradable and ready to feed the anaerobic digestion
329 process. A high concentration of VFA was measured in HBW of ASF traducing the beginning
330 of acidogenesis of ASF.

331 Methane production from the ASF from HBW was high, about 525 LCH₄.kgVS⁻¹. BMP
332 of SBW was not measured, but BMP of ASF mix, 340 LCH₄.kgVS⁻¹, resulting from SBW and
333 HBW mixing involve a recalculated BMP of about 300 LCH₄.kgVS⁻¹ considering VS of each
334 fraction.

335

336 *3.2.2. Performance of mesophilic anaerobic digestion on ASF mix*

337 No drop of pH was observed during this run. After 10 days, VFA started increasing from
338 day 10 and continued in this trend until day 18, when a decreasing trend started. The overall
339 anaerobic process and methane production were not inhibited by the low concentrations of
340 VFA, indicating that the VFAs produced by acidogens were simultaneously consumed by
341 methanogens for biogas production (Mu et al., 2018). The system did not show any upset to its
342 stability, thus indicating good robustness of the process also in transient conditions, a relevant
343 aspect for the full-scale implementation of the process. As for pH, this remained constant,
344 particularly in steady state conditions, with an average value around 7.7 because of the high
345 buffer capacity of the system.

346 The average content of TS in the reactor remained almost constant with an average value
347 of 38 gTS.kg⁻¹ (st. dev. ± 0.5) and an average VS content of 26 gVS.kg⁻¹ (st. dev. ± 0.7). The
348 ratio between VS and TS showed an average value of 69%. It was also observed the capability
349 of the system to convert the organic matter into biogas, with a conversion yield around 77%.

350 Ammonium in the liquid phase was around 1064 mg N-NH₄.L⁻¹, below the critical level
351 for inhibition (Yenigün and Demirel, 2013). This value is sufficient to provide enough

352 bioavailable nitrogen for microbe growth without causing any inhibition (Nguyen et al., 2016).
353 The value is related to the high degradation of the pressed biowaste liquid fraction that leads to
354 a rapid release of ammonium in the liquid phase due to protein deterioration (Micolucci et al.,
355 2014, Micolucci et al., 2016). The free ammonia nitrogen can be a significant inhibitor of CH₄
356 yield, as reported by Kong et al. (2016) that found that increasing from 30 to 140 mg.L⁻¹ resulted
357 in a 25% methane yield reduction.

358 The soluble COD remained almost constant and relatively low with an average value of
359 3.5 gCOD.L⁻¹. Stable performance was observed all along the run with no decrease in
360 performance. The process was able to consume a high rate of COD load with a yield of 81%.
361 Kong et al (2016) investigated CH₄ yield from high-pressure extruded food waste, as well as
362 the VS and soluble COD removal efficiencies. The VS removal efficiencies were similar,
363 achieving 73%. The highest COD_{soluble} removal efficiency obtained was 69%.

364 The average biogas composition was 57% CH₄ and the remaining part CO₂. The average
365 specific methane production was found around 345 LCH₄.kgVS⁻¹. Comparatively, BMP of ASF
366 mix was about 340 LCH₄.kgVS⁻¹. This result highlights the capability of the system to convert
367 organic matter into biogas with a high conversion yield. The value of methane production was
368 similar to other researches that used the biowaste liquid fraction, Zang et al. (2013) obtained
369 659 LCH₄.kgVS⁻¹ and Micolucci et al. (2016) achieved an average biogas production of 79
370 LCH₄.kgVS⁻¹ with 66% methane content.

371 The mesophilic digestion process of ASF mix at OLR of 3.5 gVS.L⁻¹.d⁻¹ in steady state
372 condition showed great resilience. In comparison with previous results from Nayono et al.
373 (2010a) and Micolucci et al. (2016) it can be suggested that at this applied OLR the reactor
374 showed a high efficiency on VS removal during transient conditions.

375

376 **4 Conclusions**

377 The production of urban biowaste cannot be reduced extensively since they result from
378 basic human activities such as alimentary needs. The implementation of relevant strategies to
379 avoid environmental impacts that these waste flows may generate, and in parallel recover
380 energy and/or materials from them, is therefore particularly necessary. Many studies have
381 already been published on biowaste composition and their possible treatments. The difficulties
382 encountered to guarantee over the long term a stable quality of the biowaste materials collected
383 in big cities suggest potential limitations in the objective of processing them into an organic
384 soil conditioner. Energy recovery would be less demanding in that respect. In this perspective,
385 anaerobic digestion is considered as a promising technique. Their pre-treatments before
386 transformation into biomethane is however often regarded as limiting these developments. The
387 present study investigated different physical pre-treatments of HBW and SBW prior to their
388 anaerobic digestion for methane production.

389 Results showed that water addition and mixing before pressing allow to extract
390 biodegradable organic compounds in high proportions from the biowaste samples. Both air-
391 compressed press PT#1 and worm screw press PT#2 were found applicable to extract digestible
392 organic fractions from urban biowaste. The most adapted solution depends on the mass flows
393 of collected biowaste, the space available for the implementing the treatments, and TS
394 concentration needed for subsequent anaerobic digestion. In case of severe space and/or time
395 limitations, worm screw press PT#2 should be selected for its simplicity of use.

396 Continuous digestion of ASF mix was experimentally validated using a lab-scale CSTR
397 bioreactor operated at $3.5 \text{ gVS.L}^{-1}.\text{d}^{-1}$ OLR. The reactor showed high removal efficiency on VS
398 (77%) and COD (81%), with a relatively high and stable methane content in the biogas
399 produced (around 57% v/v).

400

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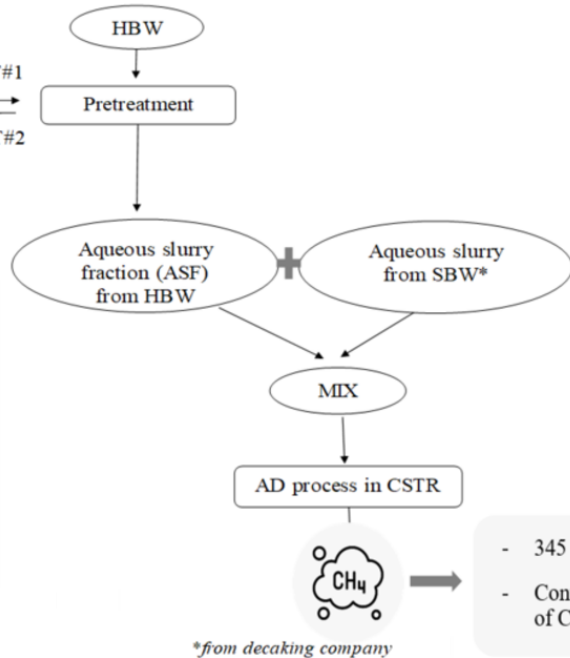
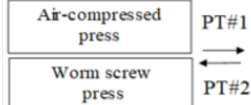
563 **List of the figure captions**

564 Fig. 1. Flowchart of global scheme of pre-treatment and anaerobic digestion process

565 Fig. 2. Evolution of mass fraction of TS and COD at different L/S ratio: 5 and 10 gWater.gTS⁻¹
566 of HBW pressed with air-compressed press (PT#1) and HBW pressed worm screw press
567 (PT#2)

568 Fig. 3. Evolution of net cumulative biomethane production through BMP test of ASF after PT#1
569 (air compressed press) and PT#2 (worm screw press) at L/S 5 ratio. Meaning of triplicated
570 assays

- BMPs (up 525 LCH₄.kgVS⁻¹)
- COD (949 gCOD.kg-1TS)



- 345 LCH₄.kgVS⁻¹
- Convert a high fraction of COD load (81%)

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