Characterization of Municipal Solid Waste to estimate biodegradability for mechanical biological pretreatment and landfilling

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Abstract:

Characterization of municipal solid waste is one of the key success of the development of biological methods of valuation of fermentable organic fractions. The present study investigated the biochemical and biodegradation characteristics of several household waste fractions and materials. The correlation between aerobic test (BOD on suspended solid samples) and anaerobic test (BMP on suspended solid samples) indicated that the biodegradability of the organic matter contained in the solid materials was related to its properties. It is also suggested that both methods could be used to evaluate the biodegradability of organic matter in waste materials. No significant correlation occurred between biodegradability with variables from leaching test (Soluble COD, conductivity, soluble fraction in solution neutral detergent) and Van't Soest fraction cellulose or hemicellulose, excepted for the non-extraction RES fraction.

Keyword: municipal solid wastes; Mechanical Biological Pretreatment (MBT), landfilling, aerobic treatment, anaerobic treatment, anaerobic digestion

List of abbreviations:

BD_{Aero}: Bioconversion yield in aerobic condition ($\%_{COD}$)

BD_{Anae}: Bioconversion yield in anaerobic condition ($\%_{COD}$)

BOD_{28}: Biological Oxygen Demand on suspended solid in liquid phase. 28 days of incubation ($mg_{O2}.g^{-1}{}_{TS}$)

BMP_{60}: BioMethane Potential on suspended material. 60 days of incubation ($NmL.g^{-1}{}_{TS}$)

CELL: Cellulose ($\%_{VS}$)

HEM: Hemicellulose ($\%_{VS}$)

PCA: Principal Component Analysis

RMSW: Residual Municipal Solid Waste

SCOD: Chemical Oxygen Demand on leachate collected from leaching test (L/S ratio = 10, contact time 3h) on solid material after filtration at 0.45 µm ($mg_{O2}.g^{-1}{}_{TS}$)

SL: Soluble fraction ($\%_{VS}$)

TCOD: Total Chemical Oxygen Demand on Solid material ($mg_{O2}.g^{-1}{}_{TS}$)

TS: Total solid ($\%_{wS}$)

VS: volatile solid ($\%_{TS}$)

wS: wet solid

1 Introduction

Efficient Municipal Solid Waste management processes have been developed in Europe as an alternative to final storage of refuse in sanitary landfill and promoting selective waste collection for material and energy recycling. The EU Council Directive 99/31/EC, intended to prevent or reduce the adverse effects of the landfill of waste on the environment, in particular on surface water, groundwater, soil, air and human health (Slack et al., 2005). Mechanical and Biological Treatment (MBT) of the MSW is a management technology to achieve these targets. MBT consists in mechanical pre-processing stages followed by biological stages that reduce and stabilize the biodegradable matter under controlled anaerobic and/or aerobic condition (Heerenklage and Stegmann, 1995; Scheelhaase and Bidlingmaier, 1997).

Characterization of municipal solid waste (MSW) is one of the key success of the development of efficient waste management processes as an alternative to final storage of refuse in sanitary landfills. This is a strong need for design of MBT processes, in particular where bioprocess such aerobic treatment (composting or biodrying process) and anaerobic digestion (AD) are integrated to the process chain. Quantification and the characterization of the biodegradable organic fraction and its variability are relatively complex and requires considerable sampling work, and analytical procedures. It's even more difficult in particular to determine the potential of bioconversion under aerobic or anaerobic conditions. Numerous research teams have attempted to develop analytical procedures with complementary characterization to assess the biodegradation potential of heterogeneous waste, like organic matter quantification, biochemical characterization, aerobic tests, and tried to find correlations models with biomethane potential (BMP) or oxygen consumption (BOD or other aerobic tests). Several studies have already investigated for residual fraction of MSW to correlate analytical methods with biological methods (Chandler et al., 1980; Eleazer et al., 1997; Cossu & Raga, 2008; Ponsá et al., 2008; Barrena et al., 2009). However, despite all the work carried out to correlate aerobic and anaerobic biodegradability with the biochemical characteristics of heterogeneous organic waste, no single variable was yet shown to allow alone a good prediction of biodegradability. In a previous study, Bayard et al. (2015) suggested that the composition of an organic substrate is not fully determinant of its biodegradability, for complex and heterogeneous waste like MSW.

Faced with the difficulty of determining the biological and biochemical characteristics of solid waste as complex as MSW, this article suggests a new approach based on the characterization of fractions defined by the standard Method MODECOM^{TM} (AFNOR NF X30-408, 2013) developed by The French Agency for Environment and Energy Management (ADEME, 1998). Our approach was to conduct an analysis of a MSW collected from a MTB plant, with determining the composition of the mixture as MODECOM^{TM} fractions. Different laboratory tests were conducted to achieve bio-chemical characterizations of selected fractions which were potentially contained biodegradable organic matter. These included organic matter quantification, leaching test to determined soluble organic matter, biochemical characterization with sequential extraction procedure to determine hemi-cellulose, cellulose, lignin-like content, and biodegradability under aerobic (BOD) and anaerobic (BMP) conditions. Principal Components Analysis (PCA) was used to investigate the relationships amongst the variables obtained from all selected fractions and compare it. Additivity of the parameters measured separately on each fraction was compared to the result obtained on waste sample recomposed of mixed fractions.

2 Materials and Methods

2.1 MSW collection and sample preparation

The French standard procedure for the determination of MSW composition (MODECOM$_{TM}$) considers 14 different major waste categories. The first and major fraction is the “Fines” waste was considered as < 20 mm after screening on a sorting table. The 12 others waste categories are: organic (putrescible waste), paper, cardboard (corrugated), complex, plastic, textile, metals, glass, special (hazardous), hygienic textile, combustible and incombustible waste (see Table 1). Out of those 13 categories, 8 of them are supposed to contain organic matter and all 9, except plastics, are composed of biodegradable organic matter and were therefore selected in this study. Some categories have been further subdivided in subcategories. Altogether, 12 different categories and subcategories were considered in the present study, as shown in Table 1.

Each of them have been collected from a MTB plant located in the South east of France. All categories were dried and subsequently shredded down to a maximum particle size of 1 mm using a RETSCH® SM 200 cutting mill. One kilogram of a MIX waste was constituted by mixing all shredded fractions in the proportions corresponding to the average composition of household waste in France (also see Table 1).

Table 1. Categories and subcategories of average MSW collected in France and MIX waste composition.

MODECOM® categories	**MSW (% w/w_{DM})**	**Sub-categories**	**Designation**	**MIX Waste (% w/w_{DM})**
Putrescible matters	11.5	Food waste	FW	6.2
		Mix of green waste (yard, leaves, branches)	GW	12.5
Fines (< 20 mm)	21.6	Fine Fraction	FF	34.9
Papers	9.7	Newsprints	NP	8.3
		Office papers	OP	6.4
		Magazines	MP	6.4
Cardboards	9.0	Corrugated board	CB	15.5
Textiles	0.3	Cotton textiles	COT	0.5
Sanitary tissues	2.3	Sanitary textiles	SAN	3.0
		Diapers	DIA	0.8
Non Classified Combustibles	3.1	Wood	WOO	5.1
Composites	1.5	Composites like “Tetrabricks”	COM	0.5
		Non-biodegradable like plastic “yoghurt pot”		100
Plastics	15.7			
Glass	9.1			
Incombustible waste	8.2			
Metals	5.5			
Special (hazardous)	2.6			
	100			

2.2. Organic matter quantification and leaching behavior

Organic content: two methods have used to quantify organic content on the solid fraction. The first one was consisted in measuring the mass loss of a dry sample burnt at 550°C for 4h, corresponding to “Volatile Solid” (VS) expressed in percent of Total Solid ($\%_{TS}$). A second method has been used to determine organic content: the Total Chemical Oxygen Demand (TCOD) by sulfochromic acid oxidation followed the international standard procedure ISO 14235 (1998) commonly used for soil samples.

Leaching behavior: The protocol used was based on the one described in the European standard leaching procedure AFNOR EN 12457-2 (2002): a dry mass of 100 g of sample was suspended in 1000 mL of de-ionized water and the suspension continuously mixed at room temperature (20 ± 2°C) on a rotating tumbler set at 10 rpm. After 3 hours, the suspensions were centrifuged at 9000 g for 20 min and the supernatants filtered at 0.45 µm. The solutions were then analyzed for Soluble Chemical Oxygen Demand (SCOD) according to the International Standard Procedure ISO 15705 (2002). Results were expressed as $mg_{O2}.g^{-1}{}_{TS}$ with respect to the dry mas of the samples, and as $\%_{COD}$ to express the proportion of SCOD in the Total COD (TCOD) of the samples.

Analytical results of total and soluble organic matter contents are shown in Table 2.

Table 2. Organic matter content and leaching behavior from categories and subcategories of waste and MIX waste.

Waste Categories	Organic matter quantifications		Leaching behavior		
	VS[b]	TCOD[b]	pH	Conductivity	Soluble COD[b]
				G	SCOD
	($\%_{TS}$)	($mg_{O2}.g^{-1}{}_{TS}$)		($\mu S.cm^{-1}$)	($mg_{O2}.g^{-1}{}_{TS}$)
Food waste (FW)	93.6 ± 0.1	1330 ± 25	5.1	4860	223.8 ± 0.5
Mix of green waste (GW)	50.4 ± 1.9	756 ± 10	6.8	2750	110.5 ± 1.2
Fine Fraction (FF)	60.4 ± 2.3	910 ± 20	5.5	7040	179.3 ± 2
Newsprints (NP)	81.0 ± 1.0	1077 ± 25	8.3	580	10.2 ± 0.7
Office papers (OP)	92.1 ± 1.1	1063 ± 12	6.4	485	9.2 ± 0.6
Magazines (MP)	54.3 ± 2.7	696 ± 25	6.4	560	14.7 ± 0.9
Corrugated board (CB)	89.0 ± 1.5	1131 ± 15	8.2	790	42.2 ± 1.4
Cotton textiles (COT)	98.9 ± 1.6	1180 ± 12	7.9	1180	12.1 ± 0.6
Sanitary textiles (SAN)	98.3 ± 1.2	1240 ± 32	6.1	560	7.9 ± 0.3
Diapers (DIA)	94.1± 2.0	1530 ± 20	8.0	430	3.0 ± 0.5
Wood (WOO)	98.3 ± 1.2	1370 ± 15	5.6	650	28.2 ± 0.4
Composites (COM)	98.6 ± 1.4	1360 ± 15	7.7	733	24.4 ± 0.4
MIX_{exp}	74 ± 2.5	1003 ± 12	7.2	4220	93.7 ± 0.8

a: average of triplicates with standard deviation in brackets; b: expressed in % w/w of Total Solid (TS);

2.3. Biochemical analysis

The biochemical fractionation of the organic matter in the samples was achieved by successive steps of hydrolysis and extraction using different solvents. The protocol was developed by Van Soest and Wine (1967) for fibrous products. It was conducted on aliquots of powdered dry samples corresponding to 2 g of volatile matter. At each step, the residual solids were dried and weighed, and their VS contents analyzed. Four fractions were obtained, namely (1) neutral detergent soluble fraction (SF) extracted at the first step by a neutral detergent aqueous solution; (2) Hemicelluloses-like (HEM) extracted with a dilute acidic aqueous detergent solution; (3) Cellulose-like (CELL) extracted with a concentrated 72% sulfuric acid solution; and (4) lignin-like residual organic matter (RES) which was not extracted in the procedure. The results were expressed in mass % of VS, *i.e.* in grams of the considered constituent present in 100 g of volatile solid. All data are presented in Table 3.

Table 3. Biochemical characterization from categories and subcategories of waste and MIX waste.

Waste Categories	Biochemical characterization			
	SF[c] ($\%_{VS}$)	HEM[c] ($\%_{VS}$)	CEL[c] ($\%_{VS}$)	RES[c] ($\%_{VS}$)
Food waste (FW)	50.9	28.3	12.1	8.7
Mix of green waste (GW)	36.8	15.8	18.4	29.0
Fine Fraction (FF)	55.6	13.9	20.3	10.2
Newsprints (NP)	8.6	8.5	74.3	8.6
Office papers (OP)	19.0	2.4	77.0	1.6
Magazines (MP)	11.3	1.1	87.0	1.0
Corrugated board (CB)	18.0	11.6	53.5	17.0
Cotton textiles (COT)	14.7	1.4	80.2	3.7
Sanitary textiles (SAN)	0.0	14.6	81.1	4.4
Diapers (DIA)	0.0	0.0	66.8	33.2
Wood (WOO)	5.0	15.0	50.0	30.0
Composites (COM)	19.6	21.0	39.3	20.1
MIX_{exp}	34.0	10.4	47.4	8.2

a: expressed in % w/w of Volatile Solid (VS).

2.4. Quantification of aerobic biodegradability: BOD and PBM tests on suspended solid sample

Aerobic assays: A static respiration activity test for suspended solid samples was developed from the classical Biological Oxygen Demand (BOD) protocol for liquid samples. The samples were suspended in an aqueous nutrient solution. The protocol followed was based on the international procedure ISO 10707 (1994). The BOD flasks were hermetically closed by a manometric cap to monitor pressure variations inside the bottles. Carbon dioxide produced from biodegradation was trapped by sodium hydroxide pellets in the headspace of the test flasks. Consequently, the recorded pressure decreased proportionally to the oxygen consumed and was subsequently converted into BOD values. The samples were incubated for 28 days at least in the dark at 30°C, in triplicates, under continuous magnetic stirring. The aerobic biodegradability was calculated as the ratio between the BOD_{28} and TCOD (eq. 1):

$$BD_{Aero} = \frac{BOD \quad (mg_{O2} \cdot g_{TS}^{-1})}{TCOD \quad (mg_{O2} \cdot g_{TS}^{-1})} \times 100 \qquad \text{(eq. 1)}$$

Anaerobic assays: Biomethane potentials (BMP) of the samples were determined with a method adapted from the standard procedure ISO 11734 (1995) dedicated to the evaluation of the anaerobic biodegradability of organic compounds in digested sludge. Samples were suspended in of nutrient medium and 200 mL of seed inoculum solution. The inoculum was collected from a sewage sludge digester. To insure anaerobic conditions, bottles containing tested materials and nutrient medium were flushed with a gas mix CO_2 and N_2 (10-90 V/V) for 5 minutes after introducing inoculum. The bottles were sealed with air-tight rubber stoppers and plastic seals, and incubated for 60 days at least at 35 ± 2°C in the dark. All the assays were performed in triplicates. A blank containing only liquid medium and seed inoculum solution was incubated and monitored in parallel with the tests. Biomethane production was monitored using a pressure transducer. Gas composition was periodically analyzed with an Agilent® gas micro-chromatograph with thermal conductivity detectors and equipped with a column Poraplot® U for CO_2 and H_2S separation and a column Molsieve® for O_2, N_2, and CH_4.

The anaerobic biodegradability was finally expressed as the ratio between CH_4 production and COD in solid as follows (eq. 2).

$$BD_{Anae} = \frac{BMP \quad (NmL_{CH4} \cdot g_{TS}^{-1})}{0{,}35 \times TCOD \quad (mg_{O2} \cdot g_{TS}^{-1})} \times 100 \qquad \text{(eq. 2)}$$

Table 4 show the results of characterization along with aerobic and anaerobic biodegradation yields and rates of each individual waste fraction and of the MIX waste.

Table 4. Experimental determinations of biological oxygen demand (BOD) and biochemical methane potential (BMP) on categories and subcategories of waste and MIX waste.

Waste Categories	Aerobic test		Ana	
	BOD_{28} [b]	BD_{Aero}	BMP_{60} [b]	BD_{Anae}
	($mg_{O2}.g^{-1}_{TS}$)	($\%_{TCOD}$)	($NmL_{CH4}.g^{-1}_{TS}$)	($\%_{TCOD}$)
Food waste (FW)	933 ± 40[a]	70.2	268 ± 11	57,5
Mix of green waste (GW)	360 ± 23	47.6	69 ± 5	26,1
Fine Fraction (FF)	747 ± 38	82.1	199 ± 6	62,4
Newsprints (NP)	708 ± 17	65.7	142 ± 5	37,6
Office papers (OP)	901 ± 36	84.7	273 ± 6	73,0
Magazines (MP)	422 ± 30	60,6	157 ± 8	64,4
Corrugated board (CB)	789 ± 39	69.7	221 ± 8	55,8
Cotton textiles (COT)	780 ± 31	66.1	275 ± 9	66,6
Sanitary textiles (SAN)	680 ± 22	54.8	266 ± 2	61,4
Diapers (DIA)	578 ± 26	37.8	221 ± 21	41,3
Wood (WOO)	129 ± 11	9.4	16 ± 1	3,3
Composites (COM)	576 ± 12	42.3	148 ± 20	31,1
MIX_{exp}	656 ± 15	65.4	148 ± 3	46,4

a: average of triplicates with standard deviation in brackets; b: expressed in % w/w of Total Solid (TS).

2.4. Statistical approach

The aim of using the Principal components analysis (PCA) was to identify the multiple correlations between the variables on the one hand, the waste fractions on the other.

Selected variables were Conductivity (G), TCOD, SCOD, biochemical characterization (Van't Soest's fractions (SF, HEM, CELL, and RES), BOD_{28}, and BMP_{60}. PCA is a multivariate statistical data reduction technique where the new variables (principal components or factors) are calculated from linear combinations of the original variables. The principal components are orthogonal to each other, so there is no redundant information. The first principal component, or factor, accounts for the greatest variability in the data. XLSTAT software (Addinsoft, SARL, France) was used to perform the PCA.

3. Results and discussion

3.1. Analytical results and general correlation using PCA

Under aerobic conditions (see Table 4), the Biological Oxygen Demands (BOD_{28}) and aerobic biodegradability (BD_{Aero}) were very different for the waste fractions studied. The Office Paper exhibited the highest biodegradability, with a BOD_{28} value of 901 $mg_{O2}.g_{TS}^{-1}$ and a BD_{Aero} as high as 85% corresponding to a nearly complete biodegradation of the material. Food Waste (FW) and fine fraction < 20 mm (FF) were also characterized by high biodegradability with respective BD_{Aero} values of 70 and 80%. Similar data was obtained on Newsprints, Magazines, Cardboards, Cotton and Sanitary Textiles with BD_{Aero} values ranging from 55 to 70%.

The fractions with the lowest biodegradability were Yard Waste and Wood. The low biodegradability of the organic matter in these two waste fractions might be due to the presence of a large amount of lignocellulose compounds, as confirmed by the van

Soest's sequential extraction, with high content of residual organic compounds (RES) in these waste fractions (see Table 3). Lignocellulosic compounds are most likely responsible for the low biodegradation (Stinson & Ham, 1995). For Diapers and Composites, the low BD_{Aero} (38 and 42%, respectively) were also consistent with the large content of non-extractable residues (RES: 33 and 20%), and very low Soluble Fraction (SF: 0 and 5%, resp.) from Van't Soest extraction (see Table 3), and low Soluble COD (SCOD: 3 and 24 $mg_{O2}.g^{-1}{}_{TS}$) from the leaching test (see Table 2) probably composed of plastic materials associated with cellulosic materials. Finally, the mixed waste (MIX) was characterized by a BOD_{28} of 660 $mg_{O2}.g_{TS}^{-1}$, corresponding to an aerobic biodegradability of around 65%.

Under anaerobic conditions (see Table 4), the highest methane yields (BMP) were obtained for Cotton Textile (COT, Office Paper (OP) and Food Waste (FW) fractions with BMP_{60} of 275, 273 and 268 $NmL_{CH4}.g_{TS}^{-1}$ respectively. The respective anaerobic biodegradability BD_{Anae} calculated from TCOD measurement on solid sample with eq. 2 were 67%, 85% and 58%. Literature data for methane yields of food waste range from 200 to 450 $NmL_{CH4}.g_{TS}^{-1}$ (Owens & Chynoweth, 1993; Eleazer et al., 1997; Jokela et al., 2005). Our result was relatively low but close to the methane yield of food waste as determined by Eleazer et al. (1997). Low methane potentials of food waste materials may be explained by their particular composition. Gunaseelan (2004) showed that different species or parts of the same fruit or vegetable could exhibit distinct methane potentials, which may explain the high variability of food waste biodegradability.

For the different paper fractions tested, results shown in Table 4 also highlighted the influence of their composition and origin on their anaerobic biodegradability. The low methane potentials measured for magazine paper might by explained by its low VS content as a result of the presence of additives. The difference of methane potentials between magazine and office papers was actually low. Newsprints are known for their higher lignin content than office paper and, thus, for their lower anaerobic biodegradability (Owens & Chynoweth, 1993).

Moreover; in spite of their quite similar organic content (VS and TCOD), Office Paper and Newsprints tested here exhibited significantly different methane yields. BMP from Office Paper was almost twice that of Newsprints, confirming the influence of lignin on methane yields. The lignin content was also probably responsible for the low potentials of wood and yard waste obtained here which were in agreement with literature data. Finally, the experimental BMP value obtained for the MIX waste, (163 $NmL_{CH4}.g_{TS}^{-1}$), was also in agreement with literature data. Owens & Chynoweth (1993) and Jokela et al. (2005) reported BMP values comprised between 100 and 200 $NmL_{CH4}.g_{TS}^{-1}$ on RMSW. But, BMP on cardboard did not confirmed this observation, with high methane yield (221 $NmL_{CH4}.g_{TS}^{-1}$) and high RES "lignin-like" content of 17%.

For the waste fractions studied here, the linear correlation obtained between aerobic and anaerobic potentials (and thus organic matter biodegradability under aerobic and anaerobic conditions) was weak but statistically significant (Pearson's correlation test, $\alpha = 0.05$). The linear tendency obtained for the remaining eleven materials was not strong (R^2 = 0.77) but clearly highlighted a common tendency as illustrated in Figure 1.

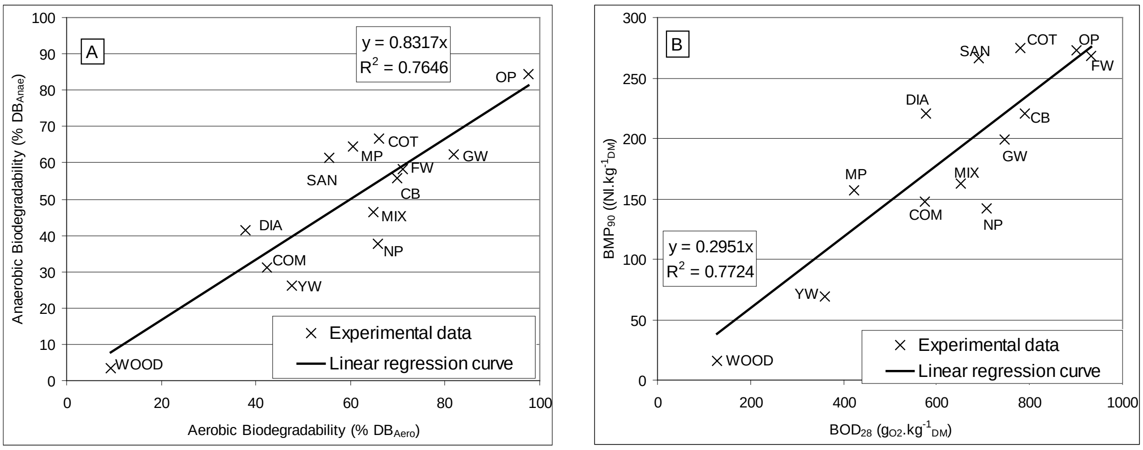
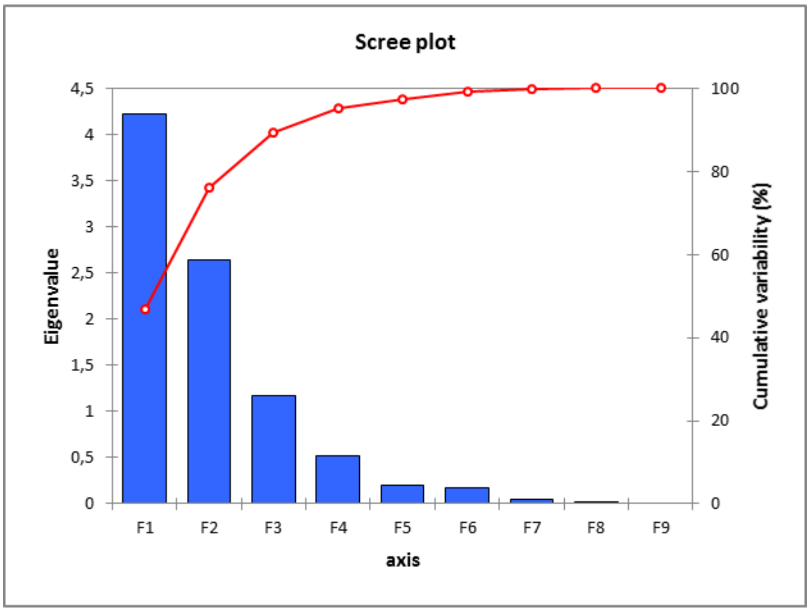


Figure 1. Linear correlations between aerobic / anaerobic biodegradability (A), and BOD_{28} / BMP_{60} (B) of categories and subcategories of waste and MIX waste.

3.2. Analytical results and general correlation using PCA

Analyses of all the selected variables were simultaneously treated in principal component analysis. PCA identified nine principal components as shown in Figure 2.



	F1	**F2**	F3	F4	F5	F6	F7	F8	F9
Eigenvalue	**4,227**	**2,636**	1,173	0,523	0,207	0,173	0,041	0,020	0,000
Variability (%)	**46,962**	**29,286**	13,036	5,813	2,295	1,922	0,459	0,226	0,000
Cumulative %	**46,962**	**76,248**	89,284	95,097	97,393	99,314	99,774	100,000	100,000

Figure 2: Results of the principal component analysis (PCA) in main components.

Only three components however had an Eigen value greater than 1, in particular the two first of them. Altogether these two components accounted for 76.2% of the inertia. Therefore, only the first two components were considered representative of the data and kept for further consideration.

In order to determine how the variables were related to each other, graphical representations were used (Figure 3) where positively correlated variables are grouped together while inversely correlated variables are located on opposite sides. Additionally, a circle of correlations was also plotted. The closer a variable is to the circle of correlation; the more important it is to interpret these components.

a : PC1xPC2 – Variables

b : PC1xPC2 – Samples + Variables (biplots)

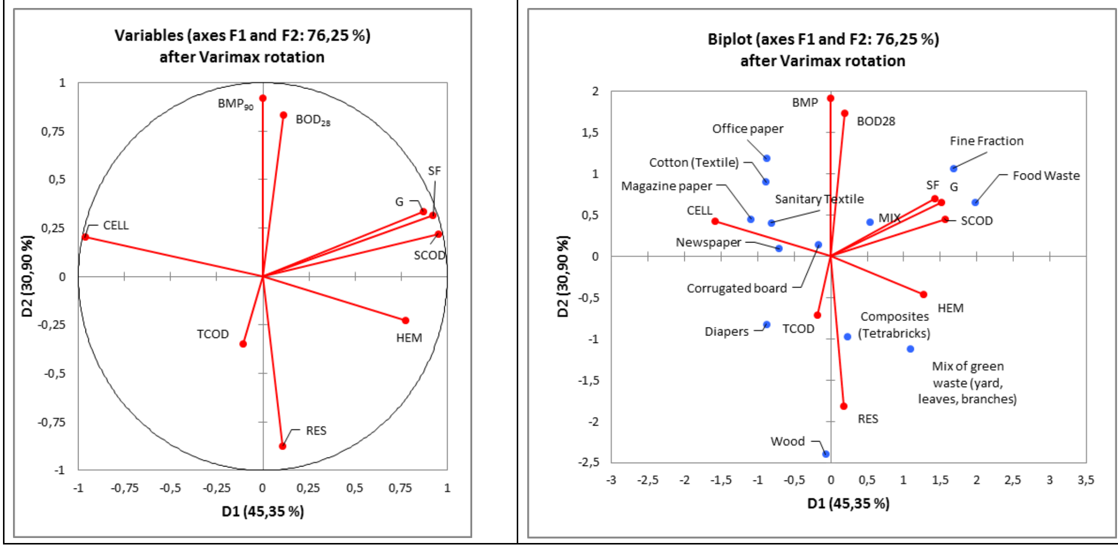


Figure 3: Plot of the loadings of the variables (a) and biplot scores (b) with principal components PC1xPC2.

It can be seen that:

- Leaching variables G and SCOD and Van't Soest's soluble fraction (SF) in neutral detergent load most significantly into the first PCA component: these three variables were strongly correlated (see also the correlation matrix, Table 5).

- If no positive correlation occurred with conductivity, SCOD and SF, with the other variables, in particular with BOD and BMP, negative correlation was observed with cellulose content CELL and G, SCOD and SF.

- Similar analysis can be done for BOD and BMP which were very close to each other and loaded to the second PCA component (F2). The second component contrasts also RES, the non-biodegradable organic matter, with BOD and BMP. RES is then strongly inversely correlated with BOD and BMP.

These results therefore indicated that the first PCA component (F1) mainly represented the characteristics of the organic content (leaching behavior in pure water or in neutral detergent solution, CELL content, and in less extent HEM content), and the second component represents the biodegradability characteristic. These data confirmed that biodegradability properties are linked together and residual content is the major variable associated to the potential of biological conversion under aerobic and anaerobic conditions.

The second step of this statistical analysis was to try to group together the different categories used (see Table 1). Figure 3b show the score plots of the variables with waste fractions and Mix. As expected, it was not so easy to distinguish the different categories. However, the following observations were made:

- “Wood” and “Green Waste” both revealed a poor biodegradable potential (negative score on F2 but F1 separated these 2 categories, suggesting that wood's organic content was higher than yard trimming's (see Figure 3b).

- “Sanitary”, “Cotton” and “Office” can be grouped together for their high biodegradable potential (Figure 3b, positive score on PCA2).

- “Food” and “Grey” categories both showed a high soluble fraction (negative score on PCA3) with an opposite organic content (see Figure 3b).

- The “Magazine” category differed in its response from the other categories with a low organic content (positive score on PCA1) and high cellulose content (positive score on PCA3).

Table 5. Correlation matrix among all parameters to compare BMP to bio-physico and chemical data.

Variables	G	TCOD	SCOD	SF	HEM	CELL	RES	BOD_{28}	BMP_{60}
G	**1**	-0,275	**0,915**	**0,920**	0,453	**-0,745**	-0,168	0,264	0,324
TCOD	-0,275	**1**	-0,177	-0,280	0,197	0,020	0,290	0,091	-0,247
SCOD	**0,915**	-0,177	**1**	**0,928**	**0,659**	**-0,860**	-0,066	0,261	0,231
SF	**0,920**	-0,280	**0,928**	**1**	**0,562**	**-0,846**	-0,151	0,357	0,262
HEM	0,453	0,197	**0,659**	**0,562**	**1**	**-0,773**	0,097	0,029	-0,253
CELL	**-0,745**	0,020	**-0,860**	**-0,846**	**-0,773**	**1**	-0,332	0,016	0,168
RES	-0,168	0,290	-0,066	-0,151	0,097	-0,332	**1**	**-0,694**	**-0,671**
BOD_{28}	0,264	0,091	0,261	0,357	0,029	0,016	**-0,694**	**1**	**0,767**
BMP_{60}	0,324	-0,247	0,231	0,262	-0,253	0,168	**-0,671**	**0,767**	**1**

Values in bold are different from 0 with a significance level alpha=0,05

5. Conclusions

The present study investigated the biochemical and biodegradation characteristics of several household waste fractions and materials. The correlation between aerobic and anaerobic biodegradations indicated that the biodegradability of the organic matter contained in the solid materials was related to its properties. It is also suggested that both methods could be used to evaluate the biodegradability of organic matter in waste materials.

However, the variability of BMP and BOD obtained for the different fractions highlighted the interest of explaining these difference in function of biochemical properties, including organic matter content, leaching and other techniques to characterize composition and structural organization of the organic matter. On the basis of this study, no correlation occurred between biodegradability with variables from leaching test and Van’t Soest sequential extraction excepted for the non-extraction RES fraction. On the other hand, this study also underlined the difficulty to implement such an approach due to the variability of the biodegradability data within a given fraction.

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