Inventory of functionalized molecules in hydrolyzed organic residues

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Abstract

The aim of this project was the assessment of organic municipal solid waste (OMSW) as source of functionalized molecules when hydrolysis was carried out enzymatically, thermo-chemically and thermo-chemically as well as enzymatically. Results revealed that OMSW is only quantitatively assessable at carbohydrate, protein and lipid levels. This is due to a changing seasonal and spacial composition, and consequently different hydrolytic products.

1. Introduction

Organic municipal solid waste (OMSW) is heterogeneous and may consist of food and kitchen wastes, paper, coffee and tea residues, grass and green clippings. An average composition (w/w) of organic municipal solid waste of 17.5% lipids, 17.7% proteins, 17.1% starch, 10.5% free sugars, 18.6% cellulose, 9.7% lignin and 8.6% hemicellulose illustrates, that the easily hydrolysable parts, such as starch, lipids and proteins, may represent 62.8% of the waste matter. Recalcitrant parts, such as cellulose, hemicellulose and lignin may represent 36.9%. A utilization approach might be the separation of present functionalized compounds as secondary raw materials directly from hydrolyzed organic matter, which can be converted into final products, such as biomaterials, biobased plasticizer, food additives and fertilizer. It is hypothesized here that this might be achieved by carrying out a sequential hydrolysis of hydrolysable parts.

The aim of this project was to carry out a characterization of functionalized molecules, such as sugars, long- and short chained fatty acids, proteins and amino acids, obtainable from OMSW using different hydrolytic treatments. For this purpose food waste and street waste have been collected and waste constituents sequentially or in one-batch approaches enzymatically, thermo-chemically or thermo-chemically as well as enzymatically hydrolyzed.

2. Results

Regarding the separation of functionalized molecules, it was first investigated whether functionalized molecules can be directly obtained from wastes by separation of liquid and solid phases. After washing of street wastes and analyzing the resulting washing water with HPLC no considerable amounts of detectable compounds were found. The supernatant of food waste fraction did reveal concentrations for glucose, fructose, sucrose and lactic acid of 25.3 g L^{-1}, 13.8 g L^{-1}, 11.2 g L^{-1} and 7.2 g L^{-1}, respectively, at a solid-to-liquid ratio of 24% (w/w).

The composition of organic waste varies not only between origins, but also due to metabolic activities of microbial consortia, nutritional habits, season and temperature. The same origin may provide organic waste with the same composition of major constituents (Tables 1 and 2), the quantity of each constituent, however, can vary and consequently an adaption of quantification methods might be necessary.

While chemical composition of all wastes was similar, the quantity varied due to different hydrolytic treatments. When materials were enzymatically or thermo-chemically as well as enzymatically treated, carbohydrate content was 200-300 mg g^{-1} in food waste 2 and in both street wastes, while food waste 1 contained around 600 mg g^{-1}. Fructose and sucrose yields differed between all wastes. The pure thermo-chemical hydrolysis with 2.5 M H_2SO_4 resulted in glucose yields of 417 mg g^{-1} and 568 mg g^{-1} in street waste 1 and 2, respectively. There was neither fructose nor sucrose detectable after chemical treatment (Table 1).

Food waste 1 and street waste 2 had a similar C-content of about 495 mg g^{-1} (Table 1). The C-content of food waste 2 and street waste 1 was 467 mg g^{-1} and 482 mg g^{-1}, respectively. N-content ranged from 14 mg g^{-1} in street waste 1, around 24 mg g^{-1} in food waste 1 and 2, and 36 mg g^{-1} in street waste 2. Correspondingly, also the protein contents ranged from 79 mg g^{-1} to 204 mg g^{-1}. All amino acids present in the hydrolysate of food waste 1 could not successfully be separated and identified. Clearly separated and identified were asparagine, valine, lysine, cysteine and tryptophan. Additionally present, but not clearly identified owing to very similar retention times, might be serine, threonine, glutamic acid, phenylalanine, asparagine, glycine, alanine, proline, tyrosine, leucine and isoleucine (not shown). Because of difficulties to separately detect all amino acids only food waste 1 was investigated.

The lipid content was between 215 mg g^{-1} and 252 mg g^{-1} in food wastes 1 and 2, respectively, and 171 mg g^{-1} and 158 mg g^{-1} in street wastes 1 and 2, respectively. The glycerol content was estimated at 10% (w/w) of the lipid content. The fatty acid profiles for food and street wastes were similar. The contents of fatty acids based on the total weight of lipids, however, slightly differed (Table 2).

3. Conclusions

From the excerpt of the results of this project it can be concluded that assessment of functionalized molecules in hydrolyzed OMSW has its limitation. Due to the heterogeneous and by time and location changing composition it seems rather impossible to provide a reliable detailed list of functionalized molecules. The question is finding the level of detail until which a characterization makes sense. This level is most likely the quantification of carbohydrates, proteins and lipids in waste material. Based on this level the possibly present functionalized molecules can theoretically be estimated in hydrolysates. Despite the challenges experienced, the potential of organic waste as a source of functionalized molecules is high. It is expected that more attention will be paid to the potential of organic waste in the future beyond its use as substrate in anaerobic digestion, composting or incineration. The matter, however, is finding the right separation technology, which is flexible enough to separate molecules from hydrolysates of varying composition obtained from different OMSW-streams.

Table 1. Constituents in organic waste materials based on dry weight (Nd = not detected; - = not analyzed). The contents/yields are based on total weight of reference substances or artificial waste.

Constituent [mg g^{-1}]	Food waste 1[b]	Food waste 2[c]	Food waste 2[b]	Street waste 1[c]	Street waste 1[e]	Street waste 2[c]	Street waste 2[e]
Total-C	495.5 ± 0.7	466.9		481.6 ± 8.8		495.0 ± 2.7	
Total-N	23.8 ± 0.2	24.9		14.1 ± 0.5		36.4 ± 2.2	
Carbohydrates (glucose/fructose/sucrose)	604.3/21.5/19.3	290.6/65.3/18.9	223.3/66.7/35.9	227.9/29.8/10.6[d]	417.3[f]	218.1/6.2/Nd[d]	567.6[f]
Lipid	214.7 ± 12.8	251.5 ± 24.6		170.6 ± 59.3		157.5 ± 17.1	
Glycerol	~22	~25		~17		~16	
Protein[a]	133.3 ± 1.1	139.4		78.9 ± 2.8		203.8 ± 12.3	
Dry matter	242.5 ± 0.4	216.9 ± 0.1		461.0 ± 44.2		302.0 ± 88.7	
Ash	60.6 ± 0.6	64.5 ± 0.5		91.8 ± 6.9		61.8 ± 19.0	
Phosphate	-	5.2		-	-	-	-

[a] Protein content was estimated by multiplying the N-content with 5.6; [b] Waste material was sequentially hydrolyzed; [c] Waste material was separately hydrolyzed; [d] Carbohydrates hydrolyzed first thermo-chemically and second enzymatically; [e] Carbohydrates hydrolyzed thermo-chemically using 2.5 M H_2SO_4; [f] Only glucose was detected.

Table 2. Fatty acid contents based on total weight of lipids detected in waste materials (Nd = not detected).

Fatty acids [mg g^{-1}]	Food waste 1	Food waste 2	Street waste 1	Street waste 2	Butter
Dodecanoic acid	Nd	Nd	3.2	16.4	1.4
Myristic acid	Traces	38.5 ± 0.2	4.9	15.7	17.8
Palmitic acid	288.3 ± 64.8	339.3 ± 9.1	384.9	311.2	44.0
Palmitoleic acid	Nd	Nd	0.3	1.6	Traces
Stearic acid	46.1 ± 9.6	54.4 ± 0.4	51.9	75.2	300.2
Oleic acid	364.9 ± 76.4	430.7 ± 2.8	435.9	393.2	635.9
Linoleic acid	106.8 ± 17.0	127.5 ± 6.8	109.4	174.8	Traces
Alpha-linolenic acid]	Traces	8.7 ± 6.0	7.0	10.3	Traces
Eicosanic acid	0.7 ± 0.2	0.9 ± 0.1	2.4	1.5	Traces