Appendix

In this attachment results of chemical analysis of several different feedstock is displayed additionally to the overview given in report (Table 3).

Biomass

Table 1: Analysis of beech wood, poplar, blend and wheat straw[1]

		Beech wood	Poplar	Blend	Wheat straw
C , d.b.	**wt.%**	49,6	48,9	47,7	42,8
H, d.b.	**wt.%**	6	5,9	5,8	5,4
O (by diff.)	**wt.%**	42,5	43,2	42,5	38,9
Water ar	**wt.%**	9	7,8	7	5,7
Ash, d.b.	**wt.%**	1,2	2	4	12,9

Table 2: Analysis of wheat straw, miscanthus and scrap wood[2]

		Wheat straw 1	Wheat straw 2	Miscanthus 1	Miscanthus 2	Scrap Wood1	Scrap Wood 2
C, d.b.	**wt.%**	43,8	46,1	48,7	48,6	47,9	49,8
H, d.b.	**wt.%**	5,9	5,7	5,5	5,9	5,7	6,1
N, d.b.	**wt.%**	<0,5	<0,5	<0,5	<0,5	2,7	<0,5
S, d.b.	**wt.%**	<1,0	<1,0	<1,0	<1,0	<1,0	<1,0
Water ar	**wt.%**	9,7	9,6	17,3	10,1	10,3	15,2
Ash, d.b.	**wt.%**	6,0	9,2	1,7	2,7	3,9	1,5

[1] A. Funke et al, Experimental comparison of two bench scale units for fast and intermediate pyrolysis; Journal of Analytical and Applied Pyrolysis, February 2017, Pages 504 - 511
[2] A. Funke et al, Fast pyrolyse char - assessment of alternative uses within the bioliq concept; Bioresource Technology Volume 200, January 2016, Pages 905-913

Table 3: Analysis of different types of biomass[3]

Feedstock	Oil				
	Moist (wt%)	Ash (wt%)	C (wt%)	H (wt%)	O (wt%)
Hardwoods					
Albizia		1,8	46	6	46
Beech		0,7	47	6	46
Eucalyptus	7,6	0,4	50	6	44
Iroko		3,5	43	5	47
Larch	9	0,2	51	7	42
Mallee		0,5	48	6	45
White Oak	10	2	50	6	43
Softwoods					
Pine	11	0,2	47	6	46
Spruce		0,4	48	6	45
E. Crops					
RCG	10	3,1	46	6	49
Tim. Grass	3,9	3,2	47	6	46
Miscanthus	8	10	48	6	46
Switchgrass	8,3	4,3	45	6	50
Willow	7,8	1,3	48	6	46
Residues					
B. Straw	8,8	5,8	48	6	45
Corncob	2	1,6	43	6	48
Cotton Stalk	8	7			
FR (Brown)	4,9	3,8	51	6	43
FR (Green)	8,1	2,1	51	6	42
Maize Stalk	8	8	49	6	43

[3] E. Butler et al, A review of recent laboratory research and commercial developments in fast pyrolysis and upgrading; Renewable and sustainable Energy Reviews; September 2011, Pages 4173 - 4180

Oreg. Stalk	9	4	43	6	2
Rice Husk	9	16	53	7	38
Wasters					
Bam. Swad.	7	2	43	6	2
Jarrop, Shell		3	50	7	38
EFBs	8	5	49	6	38
MacroAlg.					
Undaria	9,5	26	34	5	57
Lamira	8	29	30	5	62
Porphyra	6	10	40	5	47

Table 4: Chemical analysis of different feedstock[4]

	Water (wt%)	**Ash_{mf} 815°C**	**$Elements_{maf}$ (wt%)**				**$Lignocelluloses_{mf}$**			
			C	**H**	**$O_{by\ difference}$**	**N**	**Cellulose**	**Hemi-Cellulose**	**Lignin**	**Extractives + ash**
Corn stover	9,1	4,3	48,2	6,2	45,1	0,5	40,7	26,6	26,0	6,6
Rape stalks	10,6	7,8	48,3	5,7	45,0	1,1	40,0	14,0	17,0	29,0
Sunflower stalks	12,4	14,4	49,9	6,3	42,9	0,9	33,0	18,0	23,0	26,0
Wheat straw	2,8	6,8	49,0	5,9	44,5	0,7	45,0	16,1	24,1	14,8
Softwood	13,5	0,5	48,8	5,6	45,6	0,0	51,6	9,2	30,6	8,7

[4] N. Tröger et al, Effect of feedstock composition on product yields and energy recovery rates of fast pyrolysis products from different straw types; Journal of Analytical and Applied Pyrolysis, December 2012, Page 158 - 165

Table 5: Fast pyrolysis feedstock[5]

FP feedstock	Hardwood		Softwood		Wheat straw		Wheat bran	
Number of runs	7,0		5,0		4,0		3,0	
Water	9,5		13,5		9,7		12,0	
Ash	1,1		0,5		6,0		5,5	
Product	wt%		wt%		wt%		wt%	
Char + Ash	18,5	±1,6	14,9	±0,7	24,5	±1,6	18,2	±0,9
Total condensate	66,5	±1,3	69,1	±1,4	51,4	±3,9	60,0	±3,5
Tar condensate	39,2	±10,6	43,2	±5,5	44,9	±4,2	47,6	±4,8
thereof H_2O	8,3	±4,0	9,3	±2,6	19,7	±4,7	16,4	±2,5
Aqueous condensate	27,3	±10,8	25,9	±5,9	6,5	±1,9	12,5	±3,3
thereof H_2O	13,2	±4,9	15,1	±3,8	4,7	±1,5	7,8	±2,1
Pyrolysis gas (difference)	15,0	±1,9	16,0	±2,1	24,1	±5,3	21,8	±4,4
Measured gas	15,6	±2,3	11,5	±0,9	21,5	±3,5	13,3	±0,5
Deficit	-0,7	±3,6	4,5	±1,4	2,6	±7,6	8,5	±3,9

Note: "Average yields of FP products in wt.% with standard deviation, referring to moist feedstock as fed into the plant. B120"

[5] E. Henrich et al; Fast pyrolysis of lignocellulosics in a twin screw mixer reactor; Fuel Processing Technology; December 2015, Page 151 - 161

Table 6: Analysis of chicken manure and pyrochar at different temperatures[6]

	Chicken Manure	Pyrochar 350°C	Pyrochar 400°C	Pyrochar 450°C	Pyrochar 500°C	Combustion Ash 815°C
C (wt.-%)	35,40	40,1	37,7	42,1	36,5	0,19
H (wt.-%)	4,78	3,07	2,37	2,3	1,71	<0,01
N (wt.-%)	5,96	7,68	5,43	4,71	3,69	<0,01
S (wt.-%)	0,78	0,49	0,54	0,83	0,85	1,77
Cl (wt.-%)	0,34	0,49	0,45	0,51	0,67	n.a.
Ca (wt.-%)	5,84	9,53	11,7	12,4	13,3	31,5
Fe (wt.-%)	0,13	0,22	0,28	0,29	0,32	0,81
K (wt.-%)	2,24	3,76	4,33	4,75	5,01	8,92
Mg (wt.-%)	0,70	1,2	1,35	1,52	1,62	3,79
Na (wt.-%)	0,26	0,44	0,49	0,56	0,59	1,67
P (wt.-%)	1,38	2,31	2,65	3,01	3,21	7,3

	Chicken Manure	Pyrochar 350°C	Pyrochar 400°C	Pyrochar 450°C	Pyrochar 500°C	Combustion Ash 815°C	Limits DüMV
Co	<1	<1	<1	2	1		<40
Cr	5,00	3	3	4	6		<300
Cu	77,00	65	70	140	86		<500
Ni	7,00	7	8	17	9		<40
Pb	<2	<2	<2	4	<2		<100
V	5,00	3	3	9	4		n.m.

[6] B. Bergfeldt et al; Recovery of Phosphorus and other Nutrients during Pyrolysis of Chicken Manure; Agriculture 2018, 8, 187; November 2018

Municipal and other waste

Table 7: Analysis of wood chips, SRF and MSW[7]

	Wood chips	SRF 1 (solid recovered fuel)	MSW (municipal solid waste)
C (wt.-% daf)	51,20	57,60	51,32
H (wt.-% daf)	6,40	7,40	7,36
O (wt.-% daf)	42,20	31,70	39,27
N (wt.-% daf)	0,17	2,40	1,64
S (wt.-% daf)	0,03	0,26	0,41
Cl (wt.-% daf)	0,00	0,64	
Moisture (wt.-%)	15,30	20,60	29,59
Ash (wt.-%)	2,52	9,39	24,66

[7] H. Mätzing et al, Modelling grate combustion of biomass and low rank fuels with CFD application; Waste Management; June 2018; Page 686 - 697

Table 8: MSW composition[8]

MSW composition	Value (wt.% as received)
Water	30,90
Bottom ash	22,00
Fly and filter ash	3,00
C	22,55
H	4,15
N	0,91
O_{diff}	14,78
Total S	0,32
Total Cl	1,39
Trace elements (chemically bound)	Value (mg/kg)
As	2,10
Sb	48,00
Cr_{ges}	290,00
Ni	1980,00
Cd	15,00
Cu	2590,00
Pb	560,00
Zn	1790,00
Hg	0,74

[8] H.Gehrmann et al; Methods for the Evaluation of Waste Treatment Processes; Journal of Engineering Hindawi Volume 2017; October 2017; Page 1 – 13

Elemental metals in MSW	Value (wt.%)
Fe	15,55
Al	1,80
Cu and brass	0,25

Table 9: Analysis of waste materials[9]

	Proximate Analysis[a]				**Ultimate Analysis[b]**				
Samples	**H_2O (%)**	**VM (%)**	**Ash (%)**	**F.C[c]**	**C (%)**	**H (%)**	**O[c] (%)**	**N (%)**	**S (%)**
Biodegradable	4,1	77,5	10	8,4	62,5	8	28,8	0,4	0,1
Textile	2,94	81,23	5,01	10,82	58,4	4,98	35,7	0,6	0,16
Nylon plastic bags	0,02	93,71	5,52	0,741	78,7	12,4	8,7	0,12	0,02
Paper	3,44	75,85	18,82	1,89	50,5	6,41	42,3	0,22	0,55
PET bottles	ND	92,26	0,19	7,55	62	4,04	33,9	0,05	0,01
MSW	3,3	79,7	9,1	7,2	63,6	8,1	27,1	0,4	0,11
RDF	1,6	86,2	7,07	4,7	66,9	8,7	23,8	0,32	0,14
Coal	1,84	38,8	31,7	27,53	80,7	3,6	9,6	1,02	5,04

Note: a Air-dried basis
b Dried ash-free basis
Calculated by difference

[9] M. Azam et al; Comparison of the combustion characteristics and kinetic study of coal, municipal solid waste, and refuse-derived fuel: Model-fitting methods; Energy Sience and Engineering; August 2019; Page 1 - 12