

Acetic acid

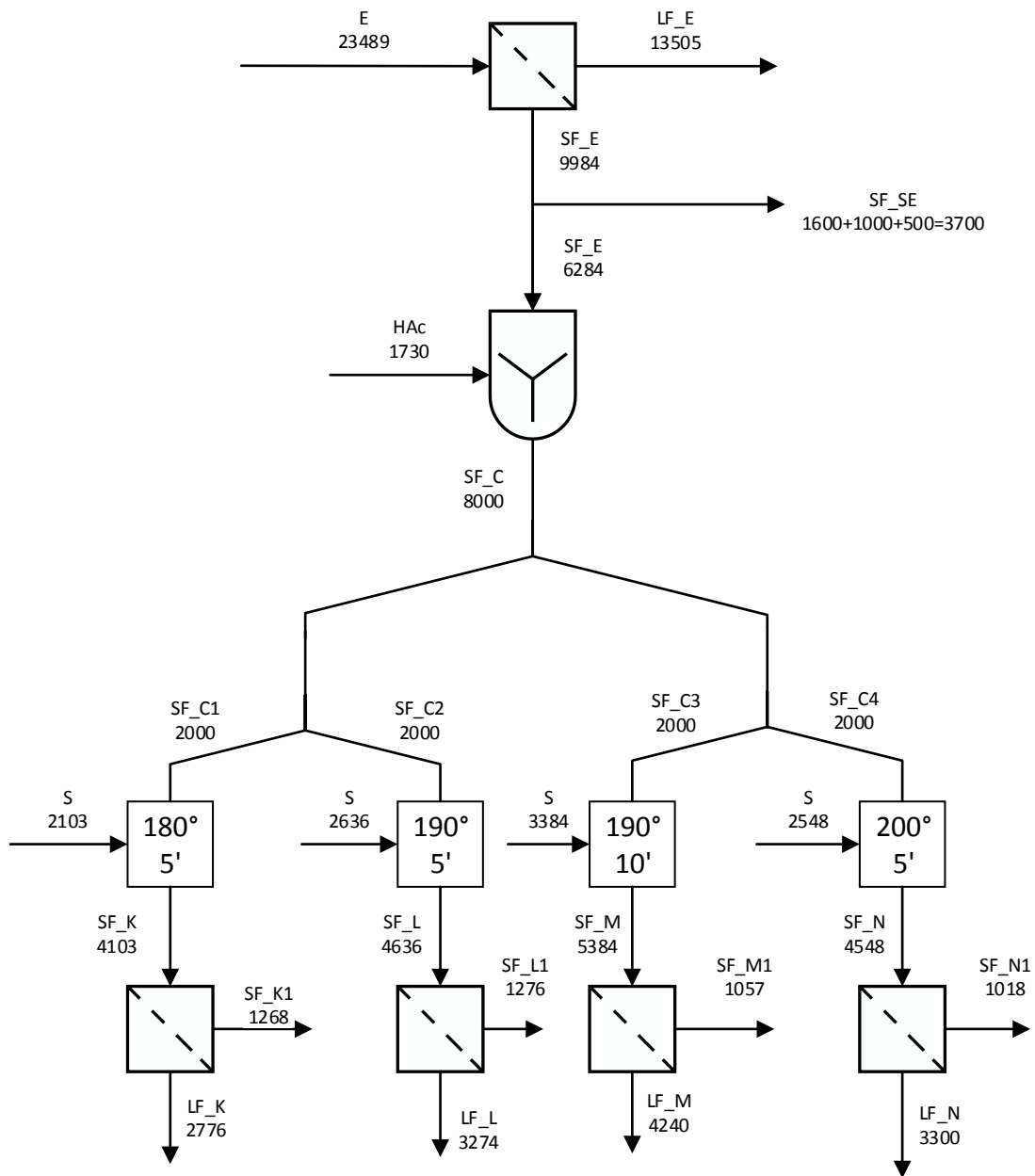


Figure 18. Specific flowsheet of the steam pretreatment of ensiled sudangrass without acetic acid catalyst. All data are presented in gram.

NaOH

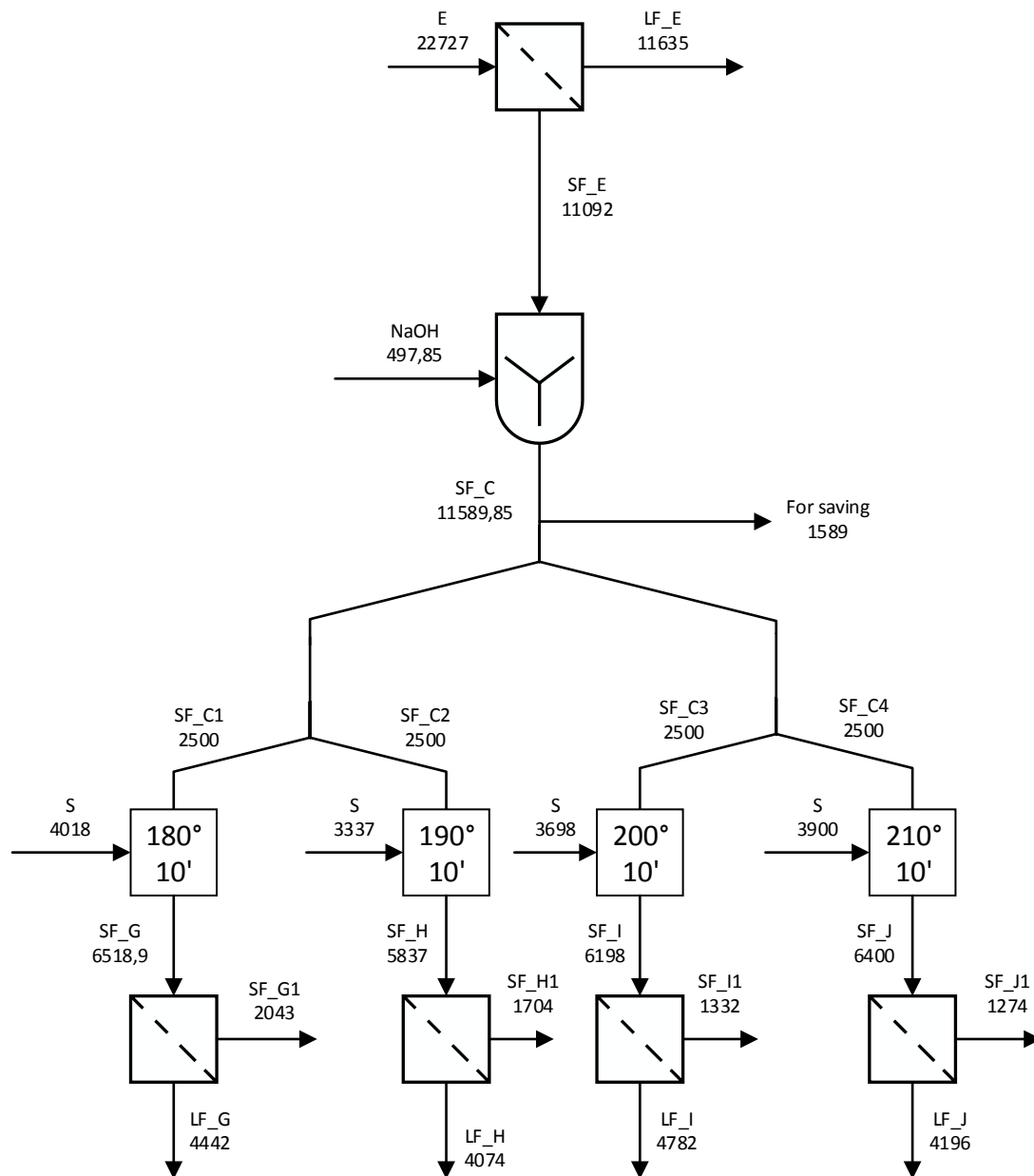


Figure 19. Specific flowsheet of the steam pretreatment of ensiled sudangrass without sodium hydroxide catalyst. All data are presented in gram.

Appendices VII

The tables 13-23 below represent data for SE of ensiled sudangrass, both for SE without catalyst and steam pretreatment with HAc and NaOH catalyst.

Table 13. Results for the ensiled sudangrass. The results are presented in g/kg TS.

Ensiled sudangrass	WIS polymers	Liquid monomers	Liquid oligomers	Sum
Glucose	185.2	0.0	0.8	186.1
Xylose	134.8	0.1	0.4	135.3
Galactose	0.0	0.0	1.0	1.0
Arabinose	23.6	0.0	0.4	24.0
Mannose	1.5	n.d.*	0.1	1.6
Acid-soluble lignin	9.3	n.d.*	n.d.*	9.3
Acid-insoluble lignin	86.8	n.d.*	n.d.*	86.8
Lactic acid	n.d.*	n.d.*	19.2	19.2
Formic acid	5.8	n.d.*	n.d.*	5.8
Acetic acid	22.6	n.d.*	32.0	54.5
Levulinic acid	7.5	n.d.*	n.d.*	7.5
Ethanol	n.d.*	n.d.*	4.7	4.7
Galacturonic acid	n.d.*	0.2	2.9	3.1
Total				539.1

Table 14. Results for the steam pretreated sudangrass, condition SE 190 10. The results are presented in g/kg TS.

SE 190 10	WIS polymers	Liquid monomers	Liquid oligomers	Sum
Glucose	170.7	0.1	3.5	174.3
Xylose	56.5	0.5	29.4	86.3
Galactose	0.0	2.8	1.2	3.9
Arabinose	0.0	1.2	3.8	5.0
Mannose	1.0	0.5	1.1	2.6
Acid-soluble lignin	4.5	n.d.*	n.d.*	4.5
Acid-insoluble lignin	74.1	n.d.*	n.d.*	74.1
Lactic acid	n.d.*	n.d.*	2.7	2.7
Formic acid	3.9	n.d.*	n.d.*	3.9
Acetic acid	9.1	19.0	1.4	29.5
Levulinic acid	6.8	n.d.*	n.d.*	6.8
Ethanol	n.d.*	n.d.*	1.6	1.6
Galacturonic acid	n.d.*	0.9	0.2	1.0
Furfural	0.3	0.2	0.4	1.0
Total				397.2

Table 15. Results for the steam pretreated sudangrass, condition SE 210 10. The results are presented in g/kg TS.

SE 210 10	WIS polymers	Liquid monomers	Liquid oligomers	Sum
Glucose	181.5	2.3	2.4	186.3
Xylose	7.5	6.6	17.7	31.8
Galactose	2.3	0.0	3.1	5.4
Arabinose	0.0	2.0	1.0	3.1
Mannose	1.2	1.5	0.6	3.3
Acid-soluble lignin	5.0	n.d.*	n.d.*	5.0
Acid-insoluble lignin	104.5	n.d.*	n.d.*	104.5
Lactic acid	n.d.*	n.d.*	9.4	9.4
Formic acid	2.1	n.d.*	n.d.*	2.1
Acetic acid	2.6	n.d.*	29.4	32.1
Levulinic acid	2.5	n.d.*	n.d.*	2.5
Ethanol	n.d.*	n.d.*	1.9	1.9
Galacturonic acid	n.d.*	n.d.*	1.0	1.0
Furfural	0.0	n.d.*	0.9	0.9
Total				389.2

Table 16. Results for the steam pretreated sudangrass, condition NaOH 180 10. The results are presented in g/kg TS.

NaOH 180 10	WIS polymers	Liquid monomers	Liquid oligomers	Sum
Glucose	143.3	0.2	2.5	146.0
Xylose	87.5	0.2	7.8	95.6
Galactose	0.0	0.2	2.6	2.8
Arabinose	13.8	0.9	3.2	17.8
Mannose	0.0	0.7	0.5	1.2
Acid-soluble lignin	2.3	n.d.*	n.d.*	2.3
Acid-insoluble lignin	66.2	n.d.*	n.d.*	66.2
Lactic acid	n.d.*	n.d.*	9.0	9.0
Formic acid	2.6	n.d.*	n.d.*	2.6
Acetic acid	10.6	n.d.*	21.8	32.4
Levulinic acid	2.5	n.d.*	n.d.*	2.5
Ethanol	n.d.*	n.d.*	1.4	1.4
Galacturonic acid	n.d.*	0.4	0.7	1.1
Furfural	n.d.*	0.0	0.1	0.2
Total				381.0

Table 17. Results for the steam pretreated sudangrass, condition NaOH 190 10. The results are presented in g/kg TS.

NaOH 190 10	WIS polymers	Liquid monomers	Liquid oligomers	Sum
Glucose	206.4	0.1	3.4	209.9
Xylose	110.2	0.2	17.2	127.6
Galactose	0.0	0.2	3.4	3.6
Arabinose	16.6	0.7	5.1	22.4
Mannose	0.0	0.7	0.7	1.4
Acid-soluble lignin	6.4	n.d.*	n.d.*	6.4
Acid-insoluble lignin	88.6	n.d.*	n.d.*	88.6
Lactic acid	n.d.*	8.4	1.8	10.2
Formic acid	3.9	n.d.*	n.d.*	3.9
Acetic acid	9.5	21.7	7.3	38.5
Levulinic acid	4.4	n.d.*	n.d.*	4.4
Ethanol	n.d.*	n.d.*	1.3	1.3
Galacturonic acid	n.d.*	0.5	0.7	1.2
Furfural	0.3	0.0	0.2	0.5
Total				519.8

Table 18. Results for the steam pretreated sudangrass, condition NaOH 200 10. The results are presented in g/kg TS.

NaOH 200 10	WIS polymers	Liquid monomers	Liquid oligomers	Sum
Glucose	192.4	0.0	3.9	196.4
Xylose	60.5	0.9	31.2	92.6
Galactose	0.0	0.3	1.5	1.8
Arabinose	2.0	1.1	5.0	8.1
Mannose	1.0	0.9	0.5	2.5
Acid-soluble lignin	5.8	n.d.*	n.d.*	5.8
Acid-insoluble lignin	102.9	n.d.*	n.d.*	102.9
Lactic acid	n.d.*	8.4	2.2	10.6
Formic acid	3.7	n.d.*	n.d.*	3.7
Acetic acid	4.2	24.7	7.9	36.8
Levulinic acid	6.6	n.d.*	n.d.*	6.6
Ethanol	n.d.*	n.d.*	1.7	1.7
Galacturonic acid	n.d.*	n.d.*	0.4	0.4
Furfural	0.3	0.1	0.3	0.7
Total				470.7

Table 19. Results for the steam pretreated sudangrass, condition NaOH 210 10. The results are presented in g/kg TS.

NaOH 210 10	WIS polymers	Liquid monomers	Liquid oligomers	Sum
Glucose	177.7	0.0	3.6	181.2
Xylose	19.4	1.6	25.6	46.6
Galactose	0.0	0.0	2.9	2.9
Arabinose	0.0	1.0	3.0	4.0
Mannose	0.0	0.9	0.7	1.6
Acid-soluble lignin	4.4	n.d.*	n.d.*	4.4
Acid-insoluble lignin	88.6	n.d.*	n.d.*	88.6
Lactic acid	n.d.*	8.2	1.7	9.9
Formic acid	2.1	n.d.*	n.d.*	2.1
Acetic acid	1.9	21.1	7.9	30.9
Levulinic acid	3.6	n.d.*	n.d.*	3.6
Ethanol	n.d.*	n.d.*	1.8	1.8
Galacturonic acid	n.d.*	0.6	0.2	0.8
Furfural	0.2	0.2	0.3	0.7
Total				379.3

Table 20. Results for the steam pretreated sudangrass, condition HAc 180 5. The results are presented in g/kg TS.

HAc 180 5	WIS polymers	Liquid monomers	Liquid oligomers	Sum
Glucose	189.9	0.5	1.8	192.2
Xylose	115.3	0.5	6.0	121.9
Galactose	0.0	0.3	2.1	2.4
Arabinose	13.3	2.1	1.9	17.3
Mannose	0.7	0.4	0.6	1.7
Acid-soluble lignin	7.9	n.d.*	n.d.*	7.9
Acid-insoluble lignin	112.6	n.d.*	n.d.*	112.6
Lactic acid	n.d.*	n.d.*	4.8	4.8
Formic acid	3.8	n.d.*	n.d.*	3.8
Acetic acid	19.2	12.4	0.3	31.9
Levulinic acid	5.1	n.d.*	n.d.*	5.1
Ethanol	n.d.*	n.d.*	0.7	0.7
Galacturonic acid	n.d.*	0.4	0.7	1.0
Furfural	0.7	0.0	0.1	0.9
Total				504.1

Table 21. Results for the steam pretreated sudangrass, condition HAc 190 5. The results are presented in g/kg TS.

HAc 190 5	WIS polymers	Liquid monomers	Liquid oligomers	Sum
Glucose	172.7	0.0	3.7	176.3
Xylose	87.1	0.1	16.8	104.1
Galactose	0.0	0.4	3.2	3.7
Arabinose	9.4	1.6	4.1	15.1
Mannose	0.8	0.9	0.7	2.4
Acid-soluble lignin	8.1	n.d.*	n.d.*	8.1
Acid-insoluble lignin	123.2	n.d.*	n.d.*	123.2
Lactic acid	n.d.*	5.5	0.6	6.2
Formic acid	6.6	n.d.*	n.d.*	6.6
Acetic acid	15.6	9.2	6.6	31.4
Levulinic acid	10.6	n.d.*	n.d.*	10.6
Ethanol	n.d.*	n.d.*	1.0	1.0
Galacturonic acid	n.d.*	0.5	0.7	1.2
Furfural	0.8	0.1	0.3	1.1
Total				490.8

Table 22. Results for the steam pretreated sudangrass, condition HAc 190 10. The results are presented in g/kg TS.

HAc 190 10	WIS polymers	Liquid monomers	Liquid oligomers	Sum
Glucose	153.4	0.0	4.4	157.8
Xylose	51.7	0.6	35.0	87.3
Galactose	0.0	1.2	3.4	4.6
Arabinose	2.9	1.6	5.1	9.6
Mannose	1.6	0.6	1.7	3.8
Acid-soluble lignin	4.6	n.d.*	n.d.*	4.6
Acid-insoluble lignin	84.8	n.d.*	n.d.*	84.8
Lactic acid	n.d.*	n.d.*	6.2	6.2
Formic acid	2.4	n.d.*	n.d.*	2.4
Acetic acid	7.7	n.d.*	21.3	29.0
Levulinic acid	3.7	n.d.*	n.d.*	3.7
Ethanol	n.d.*	n.d.*	1.5	1.5
Galacturonic acid	n.d.*	1.1	0.0	1.2
Furfural	0.2	0.3	0.4	0.9
Total				397.3

Table 23. Results for the steam pretreated sudangrass, condition HAc 200 5. The results are presented in g/kg TS.

HAc 200 5	WIS polymers	Liquid monomers	Liquid oligomers	Sum
Glucose	161.4	0.0	2.8	164.2
Xylose	58.2	0.5	21.9	80.6
Galactose	0.0	1.2	1.6	2.8
Arabinose	1.2	1.3	3.0	5.5
Mannose	0.6	0.5	0.9	1.9
Acid-soluble lignin	5.9	n.d.*	n.d.*	5.9
Acid-insoluble lignin	106.4	n.d.*	n.d.*	106.4
Lactic acid	n.d.*	n.d.*	4.1	4.1
Formic acid	3.4	n.d.*	n.d.*	3.4
Acetic acid	10.7	n.d.*	9.6	20.3
Levulinic acid	4.8	n.d.*	n.d.*	4.8
Ethanol	n.d.*	n.d.*	0.8	0.8
Galacturonic acid	n.d.*	n.d.*	0.6	0.6
Furfural	0.5	0.2	0.3	1.0
Total				402.3

Appendices VIII

Shows the results for the pretreated solid fraction of the ensiled sudangrass NaOH 180 °C 10 min) for validation. The three scenarios were (1) complete extraction, (2) WIS followed by ethanol extraction and (3) only WIS. The results can be seen in Table 24. Table 25 shows the sum of the water and ethanol extractives in the untreated sudangrass solid fraction and in the solid fraction of pretreatment NaOH 180 °C 10 min.

Table 24. Composition of structural carbohydrates, lignin and byproducts for the solid fraction of sudangrass silage (pretreatment NaOH 180 °C 10 min). Expressed as g per 1 kg TS sudangrass silage input to the steam pretreatment scheme.

	Complete extraction	WIS + Ethanol extraction	WIS
AIL	242.8	54.5	66.2
ASL	20.4	4.3	2.3
Glucose	564.7	124.1	143.3
Xylose	420.5	87.6	87.5
Galactose	0.0	0.0	0.0
Arabinose	38.3	6.7	13.8
Mannose	3.9	1.5	0.0
Lactic acid	6.4	0.8	3.0
Glycerol	0.8	0.2	0.6
Formic acid	11.6	2.7	2.6
Acetic acid	42.7	9.0	10.6
Levulinic acid	16.2	3.9	2.5
Ethanol	5.3	1.3	1.6
HMF	8.9	3.0	2.7
Furfural	61.0	13.3	0.2
Galacturonic acid	4.1	0.0	1.0
Glucuronic acid	4.3	1.4	1.7

Table 25. Shows the extractives as g per 1 kg TS sudangrass silage input to the steam pretreatment scheme. B is the untreated ensiled sudangrass and G is the solid fraction of sudangrass silage (pretreatment NaOH 180 °C 10 min).

Condition	Extractives
B	260.9
G	217.9

Appendices IX

Table 26 below shows the pH of steam pretreated materials liquid fraction.

Table 26. pH of steam pretreated materials liquid fraction.

Conditions	pH
SE 190 10	4.29
SE 210 10	3.87
NaOH 180 10	4.88
NaOH 190 10	5.04
NaOH 200 10	4.73
NaOH 210 10	4.5
HAc 180 5	4.34
HAc 190 5	4.21
HAc 190 10	4.11
HAc 200 5	4.23