Assignment 4 Biorefinery 2021

Solution to question 1

The mass of lignin in softwood chips:

1000 × 30% = 300 (metric tonne/day)

The mass of AVAP solution used to treat softwood chips:

1000 × 4 = 4000 (metric tonne/day)

The mass of water in AVAP solution:

44% × 4.000 = 1760 (metric tonne/day)

The mass of dissolved xylan in the aqueous solution after AVAP treatment: 6% × 1000 = 60 (metric tonne/day)

The mass of dissolved galactoglucomannan in the aqueous solution after AVAP treatment: 16% × 1000 = 160 (metric tonne/day)

The mass of dissolved lignin in in the aqueous solution after SO2 and ethanol evaporated: 50% × 300 x 0.965 = 144.75 (metric tonne/day)

The mass of the aqueous solution after SO2 and ethanol evaporated = the mass of dissolved xylan + the mass of dissolved galactoglucomannan + the mass of dissolved lignin in the aqueous solution after SO2 and ethanol evaporated + the mass of added water = 60 + 160 + 150 x 0.965 x 0.5 + 1760 x 2/3 = 1465.7 (metric tonne/day)

Hydrolysis stoichiometry equation of xylan:

(C5H8O4)n + nH2O 🡪 nC5H10O5

The mass of xylose after xylan is fully hydrolysis = = 68.182 (metric tonne/day)

Hydrolysis stoichiometry equation of galactoglucomannan

3(C6H10O5)n + 3nH2O 🡪 nC6H10O6 (galactose) + nC6H10O6 (glucose) + nC6H10O6 (mannose)

The mass of galactose + glucose + mannose after galactoglucomannan is fully hydrolysis = = 177.78 (metric tonne/day)

a. The concentration of xylose in aqueous solution = 68.182/1475.7= 0.0462 (metric tonne/metric tonne) = 46.2 (grams/kg solution)

The concentration of galactose + glucose + mannose in aqueous solution = = 0.1213 (metric tonne/metric tonne) = 121.3 (grams/kg solution)

The sum of the concentration of xylose, galactose, glucose and mannose in aqueous solution = 46.2 + 121.3 = 167.5 (grams/kg solution)

In comparison to the results in Table 5 of the 2020 paper by Iakovlev *et al.* in Bioresource Technology, the sum of the concentration of xylose, galactose, glucose and mannose (16.8%, wt%) is lower than the value of 22.44% for spruce in the 2020 article of Iakovlev *et al.* The explanation for the difference is that 6% xylan and 16% GGM dissolution is too low.

b. The concentration of dissolved lignin in aqueous solution = = 0.0490 (metric tonne/metric tonne) = 49 (grams/kg solution)

Solution to question 2

The mechanism of xylan dissolution is acid hydrolysis of xylan to low DP (DP less than about 6) oligomers which are soluble in water as well as xylose. The acidity during steam explosion comes from acetic acid which is released from xylan by hydrolysis of the acetyl groups attached to the xylan. Therefore the hydrolysis during steam explosion is called autohydrolysis. During acid pretreatment, the acid (normally a strong acid such as sulfuric acid) is added to the solution used for pretreatment. The net effect is that a significant amount of xylan is removed from the corn stover.

Lignin is mostly not removed from corn stover, i.e. part of the lignin softens and moves to the surface of the fibers and into the lumen cavities. A small percentage of the lignin (about 0.5-1% on oven dry corn stover) goes into solution by acid hydrolysis. This dissolved lignin presents a problem because it repolymerizes (i.e. new carbon bonds are created between lignin fragments and the polymerized lignin becomes insoluble and precipitates on surfaces. This precipitated lignin is sticky, and causes plugging in the pipes, pumps and reactors, which leads to a shutdown of the continuous operation requiring a cleaning cycle with NaOH solution. This makes the commercial operation uneconomical.