As shown on Fig.4, the increasing substrate concentration would also increase the outlet ethanol concentration. This because ethanol was a growth-associated product and therefore the increase in cell concentration would result in the increase in ethanol concentration. Inline with cell concentration, at low inlet substrate concentration (50 g/l), the higher values of hydraulic retention time would increase the substrate conversion, and hence rose the ethanol concentration. At higher substrate inlet concentration (100 and 150 g/l), the ethanol concentrations tended to decrease at increasing hydraulic retention time, although the substrate conversion still remained increasing as also shown at low inlet concentration. The higher values of ethanol concentration produced at higher substrate concentration could cause the product inhibition on growth and hence resulted in lowering cell concentration with hydraulic retention time.

Productivity is defined as the ratio of ethanol concentration to the hydraulic retention time. From Fig. 5 it can be seen that at low inlet substrate concentration (50 g/l), the ethanol productivity increased up to the maximum value and then declined with hydraulic retention time. However, the increasing amount was not significant. Therefore, low hydraulic retention time was preferred as this would require smaller reactor size. The ethanol productivity tended to decrease at increasing hydraulic retention time at higher substrate inlet concentration (100 and 150 g/l). As summarized in Table 2, the ethanol productivity showed maximum value of 0.1091, 0.3163, and 0.5639 g/l.h which were achieved at hydraulic retention time of 20 hours and inlet substrate concentration of 50, 100 and 150 g/l, respectively. This showed that operating reactor at low hydraulic retention time was favorable. However, it was not recommended to operate the reactor at very low hydraulic retention time since this would cause the cell not able to grow (wash out) and hence no ethanol would be produced.

TABLE 2
SUMMARY OF SIMULATION RESULTS

Si	Recommended R value	P [g/l]	Productivity [g/l.h]
50	20	2.1829	0.1091
100	20	6.3263	0.3163
150	20	11.2783	0.5639

From Table 2, it can be seen that the maximum ethanol of 2.1829, 6.3263 and 11.2783 g/l were obtained at 20 h hydraulic retention time by using inlet substrate concentration of 50, 100 and 150 g/l respectively.

IV. CONCLUSION

Mathematical model of continuous cheese whey fermentation based on mass balance was established. Steady state simulation results for various hydraulic retention time and inlet substrate concentration showed that maximum ethanol productivity was achieved at low value of hydraulic retention time. The higher the inlet substrate concentration the higher the ethanol concentration and productivity would be. The hydraulic retention time of 20 hours resulted in maximum ethanol productivity in the range of inlet substrate concentration used. Therefore it can be concluded that operating reactor at low hydraulic retention time is favorable.

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