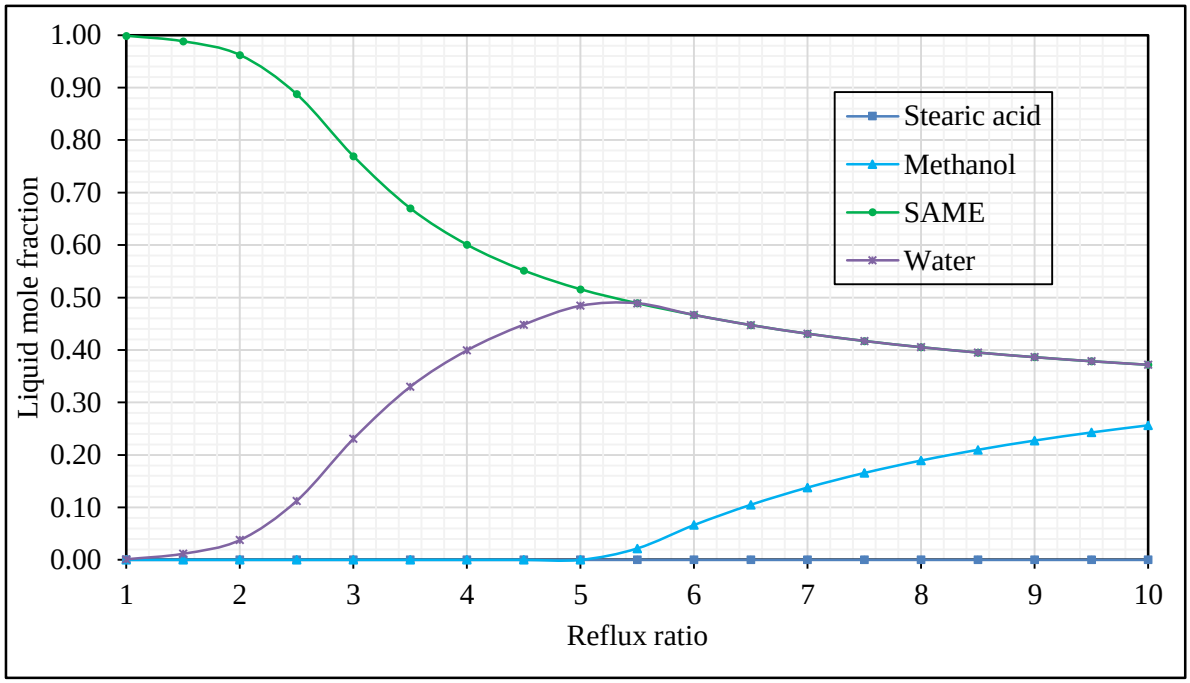

Figure 3: Effect of reflux ratio on the composition of bottom product of the process

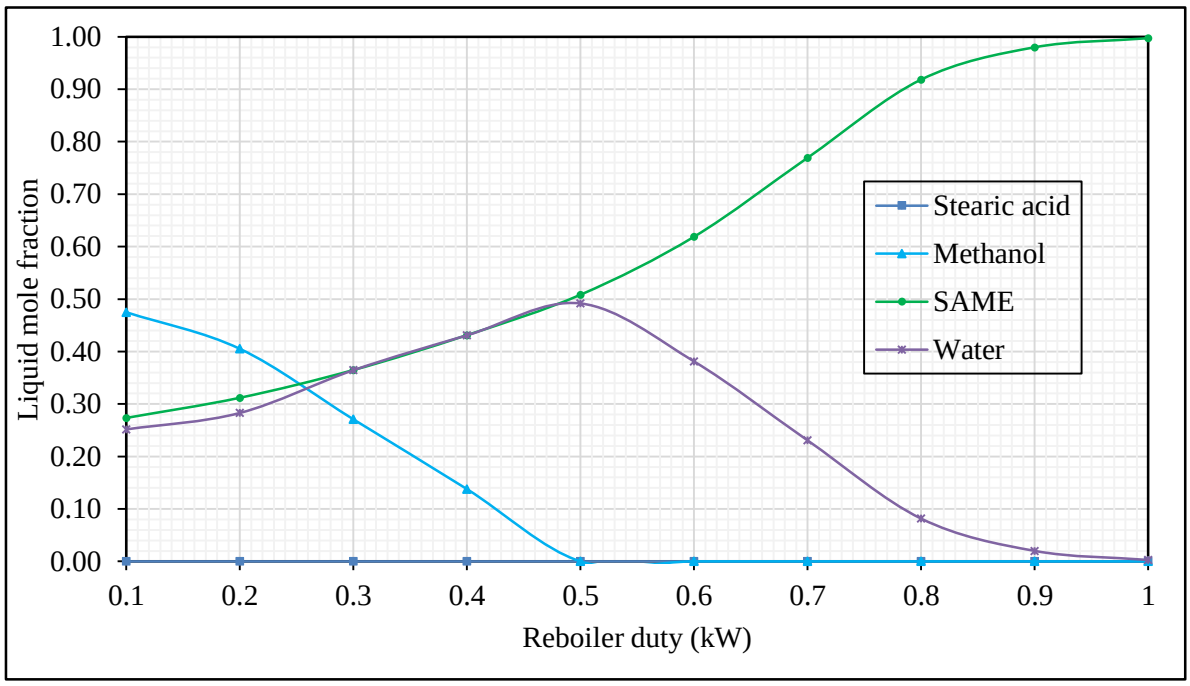

Figure 4: Effect of reboiler duty on the composition of bottom product of the process

Based on this, the interactions of the operating parameters (reflux ratio and reboiler duty) investigated were plotted together, as shown in Figure 5, to estimate their point of intersection, and this point was obtained to be reflux ratio of 5 and a reboiler duty of 0.5 kW. Using these values of the point of intersection to run the developed model of the reaction integrated distillation process, the mole fraction of the biodiesel (SAME) obtained was found to be 0.4062. This value was observed not to be favourable, and, hence, it was deemed necessary to find the best operating parameters that would give a product having high mole fraction of SAME, and the process optimization was, therefore, carried out with the aid of Aspen PLUS.

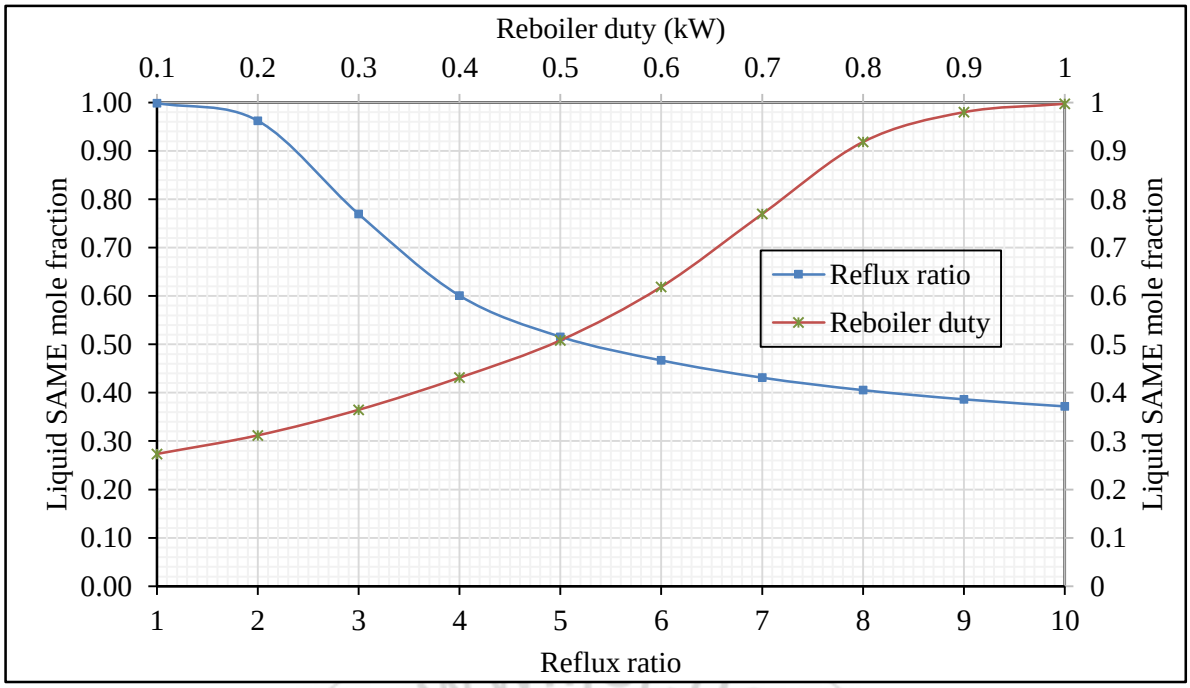

Figure 5: Liquid SAME mole fraction obtained from the separate interactions of the parameters

The results obtained from the optimization carried out in which the maximization of the mole fraction of SAME obtained from the bottom section of the column was taken as the objective function are given in Table 3. According to the table, SAME (the biodiesel produced) having purity as high as a mole fraction of 0.9993 was theoretically obtained as the product when the optimum values of the reflux ratio and the reboiler duty were 2.23 and 0.90 kW, respectively.

Table 3: Optimum parameters of the process

Parameter	Value
Reflux ratio	2.23
Reboiler duty (kW)	0.90
Objective function (Bottom SAME mole fraction)	0.9993

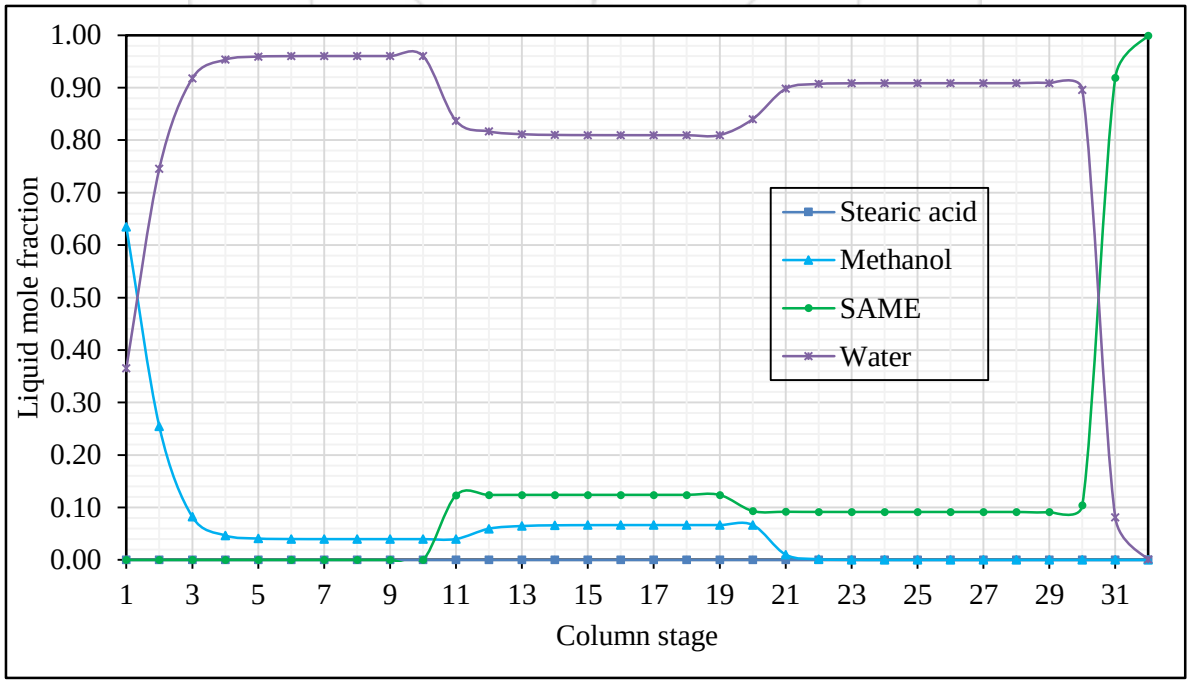

Figure 6: Liquid mole fraction profiles obtained from the optimization of the developed Aspen PLUS model.

In order to validate the values obtained from the optimization carried out, the estimated optimum values of the operating parameters were used to run the developed model of the plant and the results obtained were as given in Figure 6 in terms of the mole fraction profiles of the components present in the column at steady state. The trends of the profiles of the components obtained (Figure 6) were found to be similar to those of the initial simulation carried out (Figure 2) except at the bottom section. Also, in this case, an increment was noticed to occur in the mole fraction of the desired product present in the bottom product of the process collected from the reboiler section.

4. Conclusion

The results obtained from the simulations of the reaction integrated distillation process used for the production of stearic acid methyl ester (SAME) carried out when the reflux ratio was varied from 1 to 10 and the reboiler duty varied from 0.1 to 1 kW revealed that high purity SAME could be obtained at a reflux ratio of 1 and a reboiler duty of 0.1 kW, separately, even though the combination of these values of the operating parameters (reflux ratio and reboiler duty) could not converge when used to run the developed model of the process. Furthermore, using the optimum reflux ratio and reboiler duty estimated to be 2.23 and 0.90 kW, respectively to run the developed Aspen PLUS process model, SAME (a biodiesel) mole fraction of 0.9993 was obtained from the bottom product of the column. Therefore, it has been discovered that each of reflux ratio and reboiler duty separately affects the operation of the reaction integrated distillation process, but in order to obtain high purity of biodiesel, their combined effects should be simultaneously studied and optimized.

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6. Nomenclature

K_{eq}	Equilibrium constant
RDBPROD	Reaction integrated distillation bottom product
RDCOLUMN	Reaction integrated distillation column
RDLFEED	Reaction integrated distillation lower feed
RDTPROD	Reaction integrated distillation top product
RDUFEED	Reaction integrated distillation upper feed
SAME	Stearic acid methyl ester

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