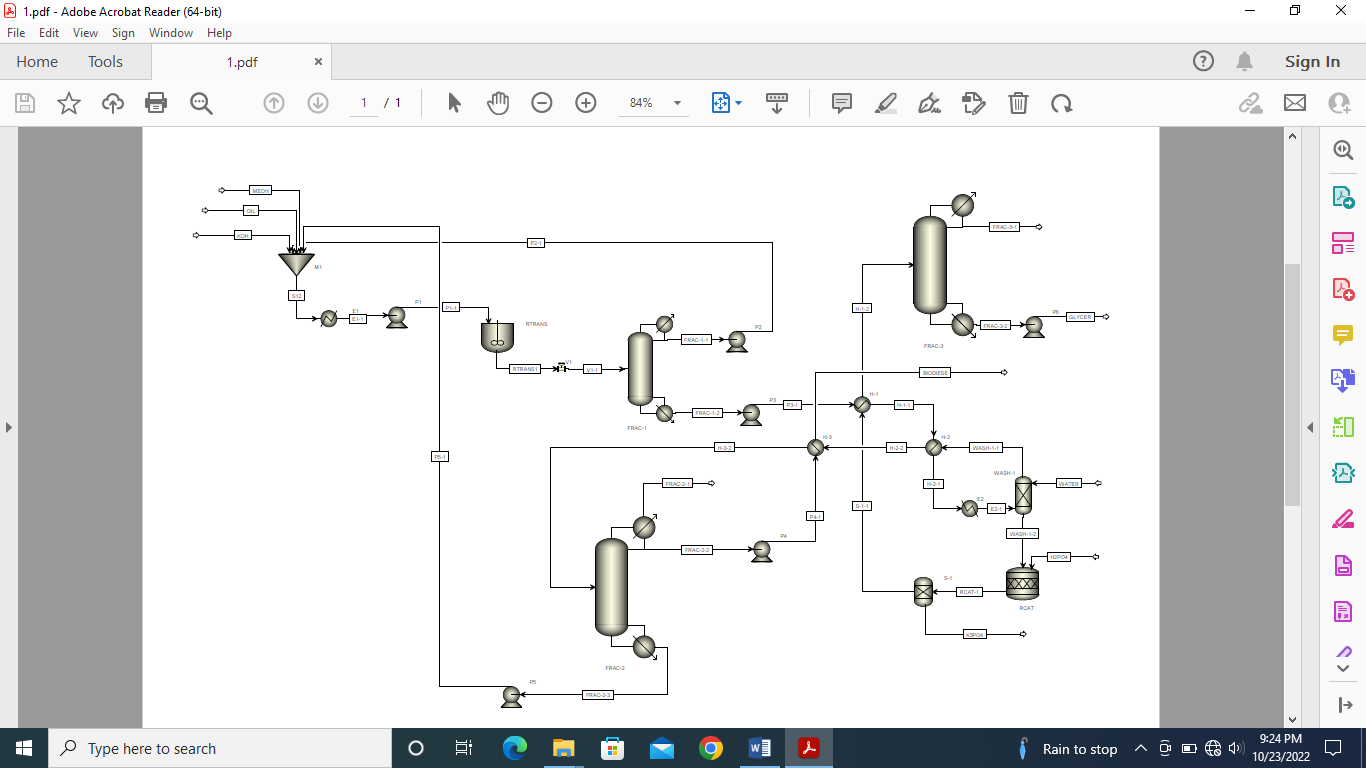
In this section, we discussed the simulation method of biodiesel production process using waste cooking oil as feedstock and the techno economics analysis of the process.

**3.1 Process Simulation**

The biodiesel production processes using waste cooking oil (shown in Figs. 1) have been simulated in the Aspen Plus V11. The process involves the trans-esterification reaction of free fatty acid in waste cooking with methanol using alkaline catalyst to produce biodiesel FAMEs. In our study, the catalyst used is KOH and we utilized a single trans-esterification reactor. In the process, waste cooking oil with a flow rate of 15,000 kg/h (stream ‘OIL’ in Fig. 1) is processed in the trans-esterification reactor (RTRANS), where FFAs react with methanol in the presence of acid catalyst to yield FAMEs. The trans-esterification reactor inlet stream is maintained at a 6:1 M ratio of methanol to oil and 1% (w/w) of KOH (stream "KOH" in Fig. 1) and operated at 50 C and 4 bar. The trans esterification reaction residence time is set to 2 hours. To maintain the necessary methanol-to-oil ratio, fresh methanol (stream "MEOH") is added in addition to the recycled methanol (stream "FRAC-1-1"). Fresh methanol is used to dissolve the anhydrous KOH. The distillation column, FRAC-1, which has 10 theoretical stages and operates at a reflux ratio of 1.0, receives the trans-esterification products (stream "RTRANS1"), where 98% of the methanol is recovered as the column top stream, "FRAC-1-1," and recycled back to the trans-esterification reactor. After passing through heat exchangers H-1 and H-2, where it is cooled using streams S-1-1 and WASH-1-1, respectively, the bottoms stream from the column (FRAC-2-2), which primarily contains biodiesels and glycerol, is charged to the WASH-1 column for extraction with water.

In "WASH-1," biodiesel and unreacted oil “WASH-1-1” are separated from methanol, glycerol, and catalyst which is then fed to distillation column (FRAC-2). The distillation column operates at a reflux ratio of 1.0, having partial condenser configuration. The overhead vapour stream "FRAC-2-1” has a low methanol content so it is not recycled to the reactor. The liquid distillate stream "FRAC-2-2” contains biodiesels with a purity level of more than 90% is separated from stream and used to heat stream "H-2-2" in exchanger H-3. Unreacted oil is recovered from the bottom stream (FRAC-2-3) of the column and is recycled and combined with new waste cooking oil. The WASH-1 column's bottom stream, which is primarily made up of glycerol (stream WASH-1-2), is sent to an R-CAT neutralization reactor to neutralize the catalyst with phosphoric acid. Equivalent moles of phosphoric acid are combined with the KOH in the WASH-1-2 stream.

After that, a separator is used to remove the produced salt (K3PO4) (K3PO4). A distillation column (FRAC-3) with 10 theoretical stages and a reflux ratio of 1.1 is used to further purify the glycerol that comes out of the neutralization reactor (RCAT). Due to its low flow rate and high methanol content, the top stream (FRAC-3-1), which primarily contains methanol and water, is not recycled. The bottom stream (FRAC-3-2) contains more than 96% pure by-product glycerol.



**FIG 1 Biodiesel Production Process Simulation in Aspen Plus**

**3.2 Techno-economic modeling**