Introduction: Production of high quality Fatty Acid Methyl Esters (FAME) or biodiesel from palm oil is simulated in a micro-porous ceramic membrane-reactor. A TiO$_2$/Al$_2$O$_3$ ceramic membrane packed with potassium hydroxide catalyst supported on palm shell activated carbon, functioning as the separator and catalytic bed.

Computational Methods: The reactor is symmetrical so only half of the system was simulated. The continuity equation is expressed by:

$$\frac{\partial(\rho e)}{\partial t} = -\nabla(\rho \vec{u} e) + \nabla(\Gamma_e \text{grade } e) + \sum S_p$$

Brinkman equation describes fluid flow in porous bed as modification to the Navier-Stokes equation:

$$\mu \nabla^2 \vec{u} - \nabla p - \frac{\mu}{k_{br}} \vec{u} = 0$$

The Maxwell-Stefan diffusion and convection equations at steady state serve as mass-balance equations in the catalytic bed:

$$\frac{\partial c_i}{\partial r} + \nabla \left( -D_i \left( \frac{\partial c_i}{\partial x} + \frac{\partial c_i}{\partial y} + \frac{\partial c_i}{\partial z} \right) \right) + u \frac{\partial c_i}{\partial x} + \frac{\partial c_i}{\partial y} + \frac{\partial c_i}{\partial z} + \beta c_i = R_i$$

$$N_i = -D_i \left( \frac{\partial c_i}{\partial x} + \frac{\partial c_i}{\partial y} + \frac{\partial c_i}{\partial z} \right) + u c_i$$

$$\nabla \left( \rho_{w} u - \rho_{w} \sum D_i \left( \nabla x_i + (d_i - \omega_i) \nabla \frac{p}{T} - D_i \nabla \frac{T}{T} \right) \right) = R_i$$

Results: The hydrodynamic results showed satisfactory agreement (maximum error of 8 %) with experimental data. The mass transfer and reaction observed maximum overestimation of 0.57% and 0.65 % respectively.

Conclusions: This work enables us to analyse the effect of porosity on hydrodynamic and mass transfer; scale up and optimise size of the membrane-reactor; and determine oil to alcohol ratio and import flow rate of material.

References: