

## Enzymatic Hydrolysis and Recycling in Ethanol Production from Oil Palm Fruit Bunch Enhanced by Nonionic Surfactants

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Nonionic surfactants with different molecular structures, namely the polyoxyethylene sorbitan monooleate (Tween 80), the secondary alcohol ethoxylate (Tergitol 15-S-9), and the branched alcohol ethoxylate (Tergitol TMN-6), were studied for their effects on the enzymatic hydrolysis of palm fruit bunch (PFB). The PFB was pretreated with a 10% w/v sodium hydroxide solution and then hydrolyzed using the cellulase enzyme from *Trichoderma reesei* (ATCC 26921) at 50 °C and pH 5. The optimal conditions providing similar yields of reducing sugar required Tween 80, Tergitol TMN-6 and Tergitol 15-S-9 at 0.25, 0.25 and 0.1% w/v, respectively. The addition of all the surfactants improved the enzymatic conversion efficiency resulting from the reduction in binding of the enzyme to lignin. In addition, the adsorption isotherm of the enzyme onto PFB was fit well by the Freundlich isotherm, while the adsorption of the three nonionic surfactants agreed well with the Langmuir isotherm. The adsorption capacities of the three nonionic surfactants were found to be well consistent with their enhancement efficiencies in enzymatic hydrolysis. The higher the critical micelle concentration (CMC) value, the higher the adsorption capacity, leading to a higher improvement of enzymatic hydrolysis. Additionally, the recycle of enzyme and surfactants was examined in order to make the process economically feasible.

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