Simulated syngas produced from biomass gasification was evaluated in a compression ignition (CI) engine under a dual fueling mode. Syngas is an economical solution with a carbon-neutral system that could replace petroleum diesel fuel. Syngas can be introduced into CI engines through a dual fueling process. However, syngas dual fueling combustion is very complicated because it consists of several combustion phases. In addition, CI engines operating under the syngas dual fueling mode suffer from low performance. Therefore, this study examined the performance of syngas dual fueling in a CI engine with blended biodiesel as pilot fuel. Two types of simulated syngas, namely typical syngas and high hydrogen syngas, were considered. The simulated high hydrogen syngas was assumed to be the product of biomass gasification with introduction of a carbon dioxide adsorption. The effect of carbon dioxide removal from syngas on the performance of syngas dual fueling in a CI engine at constant engine speed, half load, and different pilot fuel substitution rates was investigated. The combustion characteristics showed a maximum pilot fuel substitution of up to 47% with simulated syngas. Better engine performance was achieved with the simulated typical syngas in terms of brake specific energy consumption and brake thermal efficiency.