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Optimization of biodiesel production from castor seed oil as an alternative fuel in sub-Saharan African countries

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Abstract

Biodiesel-fuelled diesel motors offer a unique chance to address two general issues confronting our worldwide society: energy utilization and global warming. Biodiesel from utilized vegetable oil is simple and has numerous natural advantages. To generate a good fuel for use in diesel motors, these triglycerides are typically transformed into individual mono-alkyl esters by base-catalysed transesterification with short-chain alcohol, normally methanol.

Initially, the transesterification reactions of castor oil with methanol were studied by employing sulphuric acid as a catalyst in an ultrasound reactor. The castor oil and the methyl ester products were characterised by diverse analytical techniques such as gas chromatography (GC-MS).

The impacts of diverse reaction variables (reaction temperature, methanol to oil ratio, reaction time, catalyst amount) on FAME yield were studied. The optimum reaction conditions of the diverse process systems were established.

The optimum operating conditions for methyl esters production using ultrasound reaction, with the castor oil was established as follows: In the presence of sulphuric acid: reaction time of 40 min at 50 ºC with methanol to oil ratio of 6:1 as well as 0.5 H_2SO_4 wt. % of oil; in the presence of unsupported castor shell catalyst: reaction time of 40 min at 50 ºC with methanol to oil ratio of 9:1 and 1 unsupported castor shell (UCS) wt.% of oil; in the presence of Co/TiO_2: reaction time 40 min at 50 ºC with methanol to oil ratio of 9:1 plus 1 Co/TiO_2 wt.% of oil.

The transesterification reaction in the presence of sulphuric acid led to higher yields of methyl esters (90%) compared to methyl ester yields (85 and 83 %) for Co/TiO_2 and UCS, respectively. The utilization of homogeneous catalysts presents several inconveniences; nevertheless, heterogeneous catalysts are exciting because their use could lead to biodiesel production in a low-cost manner.

Therefore, a solid base catalyst (UCS) was prepared from a castor shell (supplied by the Mpumalanga caster plant) and Co/TiO_2 was prepared by the incipient wetness impregnation method. Numerous analytical techniques were applied for characterization purposes.

EDS results showed that the UCS predominantly contained some elements such as calcium, oxygen, and potassium, and Co/TiO_2 contained titanium, followed by cobalt.

The high amount of calcium (Ca), carbon (C), and oxygen (O) in the UCS was beneficial because their combination probably leads to the formation of CaO or $CaCO_3$, which could increase the activity of the UCS catalyst. The presence of CaO and $CaCO_3$ was confirmed by Fourier- transform infrared. The XRD characterization of the castor shell reveal the presence of $CaCO_3$ peaks only, while XRD characterization of Co/TiO_2 indicated that the diffraction

peaks at ca. 2θ = 31, 59, and 65° were observed only in the 10% Co/TiO_2 catalyst data (pattern a) and can be ascribed to Co_3O_4 resulting from the decomposition of $Co(NO_3)_2.6H_2O$ during catalyst calcination in air. The BET described the specific surface area and pore volume distribution for 10% Co/TiO_2 catalyst, blank support TiO_2, and UCS catalyst. The assessment indicated that the specific surface and volume distribution for the Co/TiO_2 catalyst where the used blank supporter TiO_2 acting as a catalyst. The volume distribution and surface area for Co/TiO_2 were greater due to the heating treatment of the catalyst system, which removed all the volatile materials. This increased the activity of the catalyst.