Chapter 2
Synthesis and Characterization of Strontium Ferrites Nanocomposites for Green Fuel Desulfurization

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ABSTRACT

$SrFe_2O_4$ nanoparticles were synthesized via a citrate–nitrate sol–gel assisted auto-combustion route and investigated as efficient heterogeneous catalysts for biodiesel production from mustard seed oil. Transesterification was carried out under varying conditions of catalyst loading, methanol-to-oil molar ratio, reaction time, and

DOI: 10.4018/979-8-3373-5966-3.ch002

temperature. The catalyst exhibited excellent activity, achieving a maximum fatty acid methyl ester (FAME) yield of 88% at optimized conditions of 100 mg catalyst loading, 3:1 methanol-to-oil ratio, 100 minutes of reaction, and 80 °C temperature. The catalytic mechanism involved Lewis acid sites (Sr^{2+}, Fe^{3+}) facilitating triglyceride activation and methanol adsorption, leading to efficient conversion of triglycerides into FAMEs. Gas chromatography (GC-FID) confirmed the composition of the obtained biodiesel, which complied with ASTM standards. Reusability studies demonstrated that the catalyst maintained 81% activity after five cycles and 69% after eight cycles, indicating high durability and stability. A comparative evaluation with reported ferrite and titanate-based nanocatalysts revealed that $SrFe_2O_4$ offers a competitive and cost-effective pathway for biodiesel synthesis under mild conditions.

1. INTRODUCTION

The global demand for renewable and eco-friendly fuels has increased in recent years due to the depletion of fossil fuel reserves and the urgent need to reduce greenhouse gas emissions (Ghamarpoor et al., 2024). Among the various renewable alternatives, biodiesel has gained significant attention because it is biodegradable, sulfur-free, and capable of reducing particulate and carbon monoxide emissions when compared with conventional diesel (Keerthana et al., 2021). Despite these benefits, biodiesel production still faces challenges such as limited catalytic efficiency, longer reaction times, and the need for effective desulfurization strategies to ensure improved combustion quality (Rashimi et al., 2017; da Silva Júnior, 2024). The search for stable, reusable, and environmentally benign catalysts is therefore a critical step in advancing biodiesel technologies. Ferrite-based nanomaterials, particularly strontium ferrites ($SrFe_2O_4$), have emerged as promising candidates for energy and environmental applications (Raza et al., 2024; Elanthamilan et al., 2023). Their unique combination of magnetic behavior, chemical stability, and redox-active Fe^{3+}/Fe^{2+} sites makes them highly effective in catalytic processes. At the nanoscale, $SrFe_2O_4$ exhibits enhanced surface area and porous structures, which enable efficient interaction with organic molecules. These properties make $SrFe_2O_4$ nanoparticles suitable for two important roles in biodiesel technology: (i) as heterogeneous catalysts in the transesterification of oils to fatty acid methyl esters (FAMEs), and (ii) as active materials for the oxidative desulfurization of sulfur-containing compounds, which improves the purity and performance of biodiesel (Subarmanian et al., 2021; Singh et al., 2022).

Recent studies on ferrite nanocatalysts have reported improved biodiesel yields, reduced methanol-to-oil ratios, and higher reusability when compared with conventional catalysts (Aziz et al., 2012; Eskandari et al., 2019; Fang et al., 2000; Hedayati