

FUEL PREPARATION, THERMOPHYSICAL PROPERTIES**MEASUREMENT, AND CHARACTERIZATION**

3.1 Preparation of Fuels**3.1.1 Preparation of Orange Peel Biodiesel, Sal Oil Biodiesel, and Its Blend**

The orange peel oil and sal seed butter is purchased from a local vendor (Jai agencies) in Varanasi, India. Required chemicals like KOH, NaOH, and Methanol are also purchased from the local vendor in Varanasi, India. The container and other apparatus are cleaned with detergent. The transesterification method is adopted to yield orange peel biodiesel and sal oil biodiesel from orange peel oil and sal seed butter. The orange peel oil and sal seed oil contains less than 2% free fatty acid, so a single-step transesterification method is adopted to produce biodiesel. The triglycerides reacted with the methanol in the existence of the KOH catalyst.



For transesterification, 1% (w/w) KOH catalyst is used, and it is conducted at 65°C temperature for 90 minutes reaction time with constant stirring at 450 rpm. The sample was prepared in a temperature-controlled chamber.

The procedures for the preparation of orange peel biodiesel are shown in Fig.3.1. Methanol 30% (by v/v) and KOH 1% (by w/w) are first measured using a borosil volume measurement flask and then premixed and poured into a borosil glass flask

purchased from a local vendor in Varanasi. Orange peel oil is heated at 55 to 60°C on a magnetic stirrer heater (TARSONS SPINOT DIGITAL MODEL MC02), and premixed methanol and KOH solution is poured into it. The mixture is stirred with a magnetic stirrer for two hours and then poured into a separator funnel and waited till ester-glycerin separation. Then separated oil is washed with hot distilled water, and OPB-water mixture is left to settle, then pure water and glycerin glimmers are separated. Finally, the OPB sample is heated for drying purposes, and OPB is derived. 10%, 20%, and 30% OPB is directly mixed with diesel fuel through a magnetic stirrer to obtain 10%, 20%, and 30% OPB-diesel blend fuel. The 10%, 20%, and 30% OPB-diesel blend fuels are named OPB10, OPB20, and OPB30, respectively.

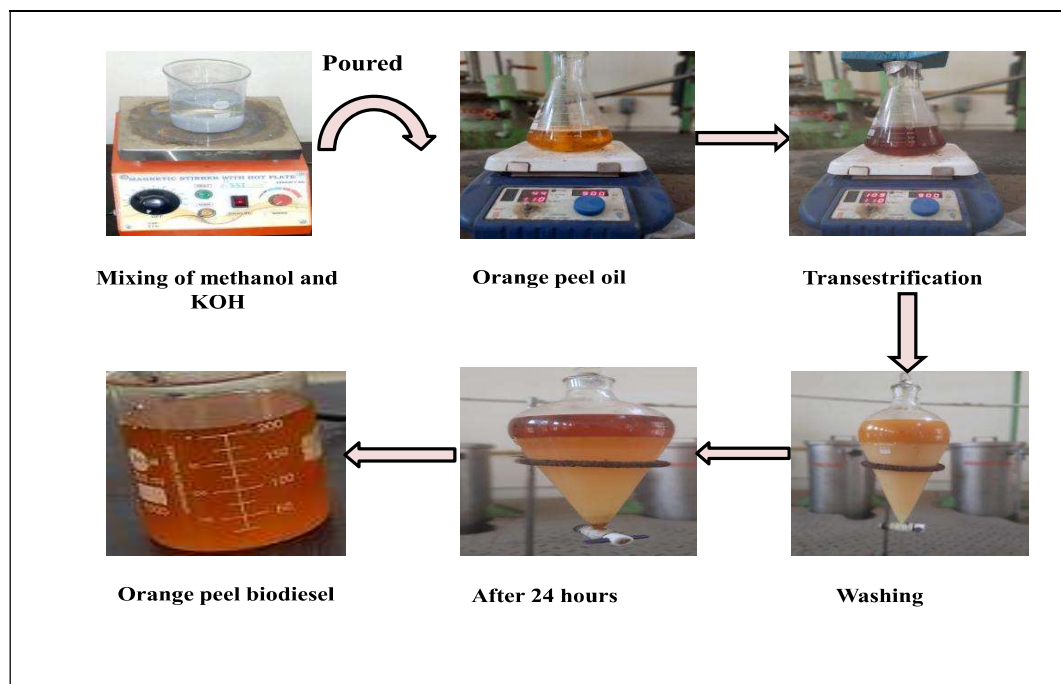


Figure 3.1 Preparation of orange peel biodiesel

The procedures for the preparation of sal oil biodiesel are shown in Fig.3.2. Sal butter is heated to convert into sal oil, sal oil is heated at 55 to 60°C on a magnetic stirrer heater, and premixed methanol and KOH solution is poured in it. The mixture is stirred with a magnetic stirrer for two hours and then poured into a separator funnel and

waited till ester–glycerin separation. Then separated oil is washed with hot distilled water, SOB–water mixture is left to settle, then pure water and glycerin glimmers are separated. Finally, the SOB sample is heated for drying purposes, and SOB is derived. The 10%, 20%, and 30% SOB are directly mixed with diesel fuel through a magnetic stirrer to obtain 10%, 20%, and 30% SOB-diesel blend fuel. The 10%, 20%, and 30% OPB-diesel blend fuels are named SOB10, SOB20, and SOB30, respectively.

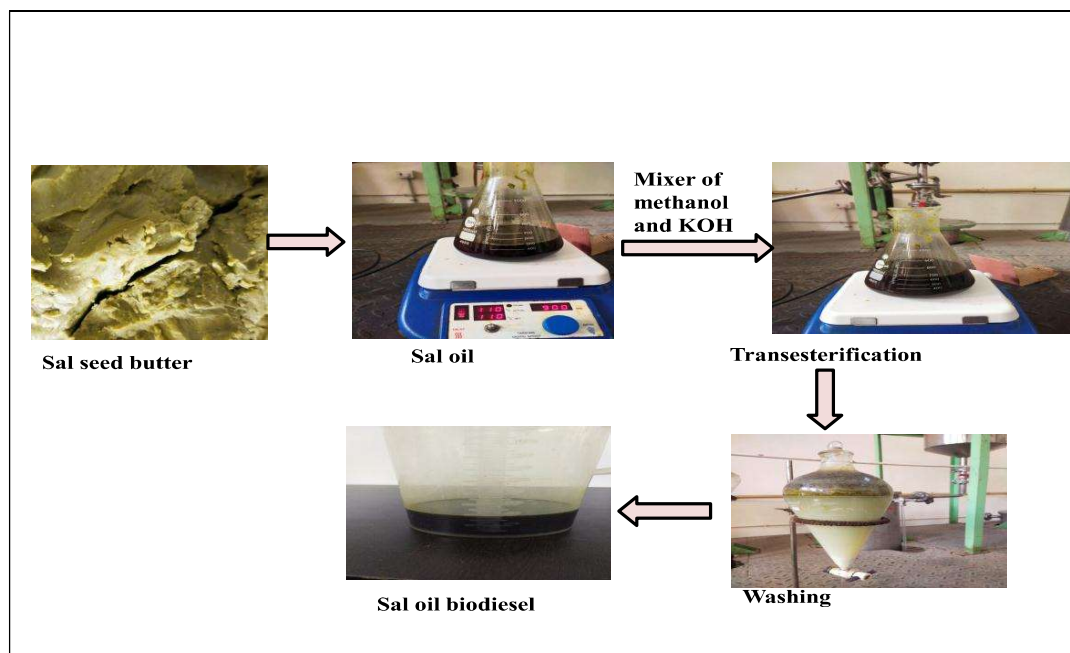


Figure 3.2 Preparation of sal oil biodiesel

3.1.2 Preparation of Water-Emulsified Fuel With Diesel

The present study uses ultrasonic vibration to prepare water in diesel emulsion fuel. An ultrasonic vibrating machine of 1.8L tank capacity made by Labman scientific instruments, India, has been used for emulsification. The vibrating frequency and the input power of the ultrasonic vibrator are set at 40kHz and 300W, respectively. The desired quantity of water (5%, 10%, and 15% of total volume), base fuel diesel (94%, 89%, and 84% of total volume), and Span 80 are taken as 1% (v/v) of the total volume in the vibrating tank. After fifty minutes of vibration, water in diesel emulsion fuel is

prepared, as shown in Fig.3.3. The 5%, 10%, and 15% water in diesel emulsion fuel are named WiDE5, WiDE10, and WiDE15, respectively.



Figure 3.3 Preparation of water-emulsified fuel

3.1.3 Preparation of Water Emulsified OPB and SOB Diesel Blend Fuel With and Without Nano Additive

To obtain the WiDE-based OPB and SOB diesel blend fuel, the first desired fraction of water, the desired fraction of OPB or SOB, Span 80 (1% v/v), and diesel fuel are poured into the vibrating tank, and the power switch of the ultrasonic vibrator has been on. After fifty minutes of vibration, water-emulsified OPB and SOB diesel blend fuel have been obtained.

To obtain the WiDE-based nano additive (Al_2O_3 and CNT) incorporated OPB and SOB diesel blend fuel, the first nano additive amounts are calculated in mg/L using a mathematical equation. Calculated amounts are weighted on an electronic weighing machine (ATX224, SHIMADZU, Japan) with ± 0.0001 accuracy. Then the water (5% v/v) and weighted nano-additive (Al_2O_3 , or CNT) are mixed by a magnetic stirrer (for thirty min, and then this nano additive incorporated water, a desired fraction of biodiesel, and Span 80 (1%v/v) is poured in the vibrating tank of the ultrasonic vibrator, and the same procedure as to obtain the WiDE-based biodiesel diesel blend

fuel are carried out. Nano additive incorporated WiDE-based biodiesel diesel blend fuel is obtained.

The comparative analysis of diesel engine is performed fuelled with WiDE5-based OPB20-diesel fuel, 50ppm Al_2O_3 nano additive incorporated WiDE5 based OPB20-diesel fuel, 50ppm CNT nano additive incorporated WiDE5 based OPB20-diesel fuel, WiDE5 based SOB20-diesel fuel, 50ppm Al_2O_3 nano additive incorporated WiDE5 based SOB20-diesel fuel, and 50ppm CNT nano additive incorporated WiDE5 based SOB20-diesel fuel. The types of fuel samples prepared for the detailed investigation of the diesel engine are shown in Fig.3.4.

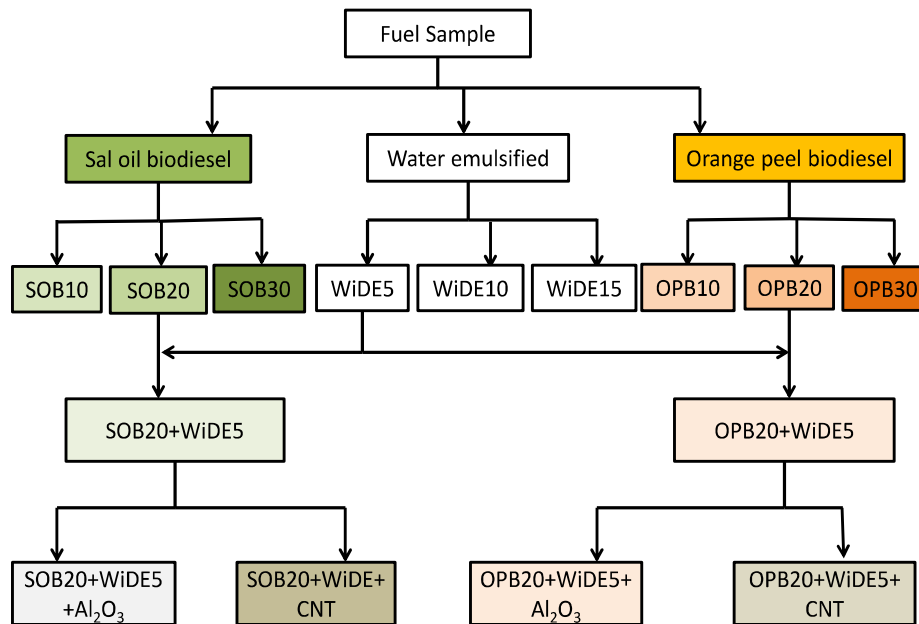


Figure 3.4 Various fuel samples prepared for experimentation

3.2 Thermo-Physical Properties Measurement

Properties, that is, density, kinematic viscosity, calorific value, flash point, and fire point of diesel fuel, water emulsified fuel, SOB blended fuels, and OPB blended

fuels with and without nano additives, are experimentally measured using various equipment. The density of the fuel is measured by mass-by-volume ratio at room temperature of 30°C. A marked beaker has been used for volume measurement and weighted using an electronic weighing machine (model: ATX224, SHIMADZU, Japan), as shown in Fig.3.5 (A). First, a specified volume of sample fuel is taken and weighted, then the weaker mass is subtracted from the weighted mass, and the ratio of actual mass to the specified volume is calculated. Kinematic viscosity is measured by DV1 Brookfield Digital Viscometer at 30°C as shown in Fig.3.5 (B) calibrated spring and a spindle are attached to a plate and submerged in the sample fuel. The viscous drag of the sample fuel between the plate and spindle is measured by spring deflection. The flash point and fire points are calculated by open-cup Cleveland apparatus, as shown in Fig.3.5(C). The fuel sample is kept in the device and heated, and the temperature of the sample is noted through a digital thermometer. The spark is shown through a matchstick at every 5°C temperature interval, and flash point temperature is noted when the first short-duration flame is shown. When the continuous flame is shown, fire point temperature is obtained. The calorific value of each fuel is measured by the digital bomb calorimeter (constant volume) made by Advance Research Instruments Company, India, as shown in Fig.3.5(D). The calorific value of fuel samples is measured according to the first law of thermodynamics (energy balance equation). The measured thermophysical properties are divided into three parts. In the first part, only diesel and water-emulsified fuel properties are measured and shown in Table 3.1. In the second part, the fuel properties of OPB-based fuel are measured and shown in Table 3.2. In the third part, the fuel properties of SOB-based oil are calculated and displayed in Table 3.3.



(A) Density measurement set-up

(B) Brookfield Digital Viscometer

(C) Open-cup Cleveland apparatus

(D) Bomb calorimeter

Figure 3.5 Thermo-physical measurement devices
Table 3.1 Thermo physical properties of water-emulsified diesel fuel

Fuel /Properties	Density (kg m ⁻³)	Kinematic viscosity (cP)	Calorific Value (MJ kg ⁻¹)	Flash Point (°C)	Fire Point (°C)
	ASTMD1298	ASTMD445	ASTMD240	ASTMD93	ASTMD93
Diesel	863	3.28	42.76	68.4	78.3
5%WiDE	870	3.39	40.88	73.7	82.3
10%WiDE	875.4	3.45	38.79	77.4	86.5
15%WiDE	882.6	3.52	36.64	81.2	89.7

Table 3.2 Thermo physical properties of OPB-based fuel

Fuel /Properties	Density (kg m ⁻³)	Kinematic viscosity (cP)	Calorific value (MJ kg ⁻¹)	Flash Point (°C)	Fire Point (°C)
OPB10	868.8	3.57	39.98	74.6	84.3
OPB20	869.4	3.73	39.64	78.7	88.6
OPB30	871.3	3.81	39.32	81.2	91.2
OPB20+5%WiDE	872	3.78	38.75	80.5	90.7
OPB20+5%WiDE+Al ₂ O ₃	874.6	3.72	39.2	78.7	87
OPB20+5%WiDE+CNT	873.5	3.74	38.9	77	85.5

Table 3.3 Thermo physical properties of SOB-based fuel

Fuel /Properties	Density (kg m ⁻³)	Kinematic viscosity (cP)	Calorific Value (MJ kg ⁻¹)	Flash Point (°C)	Fire Point (°C)
SOB10	870	3.49	38.66	77.4	87.2
SOB20	872.4	3.56	37.92	79.8	90.2
SOB30	875.6	3.70	37.44	82.6	93.5
SOB20+5%WiDE	874	3.64	37.10	81.8	92
SOB20+5%WiDE+Al ₂ O ₃	876.2	3.62	38.20	80.3	89.5
SOB20+5%WiDE+CNT	874.8	3.63	37.54	78.7	87.2

3.3 Morphology Characteristic Analysis for Al₂O₃ and CNT Nano Additive

SEM and EDS have performed the morphology characteristic analysis. The SEM is an electron microscope that forms images by flashing them with a concentrated beam of electrons. The electrons collaborate with the atom in a sample, generating different signals with information on the sample surface choreography and configuration. The configurations of Al₂O₃ and CNT fuels were developed by the SEM and are presented in Fig.3.6 (A) and Fig.3.6 (B), respectively. In the generated image of Al₂O₃ nano additive and CNT nano additive fuels, the configuration of the Al₂O₃ nano additive fuel was found spherical, and the configuration of CNT fuel was found cylindrical with less than 100 nm sizes. However, the EDS technique has been adopted to analyze the composition of processed fuel samples. The presence of ingredients in the fuel samples is analyzed by enforcing the photon nature of the light. A digital quantum counting technique causes the energy propagation spectrometry signal predictable. A semiconductor component is adapted for the examination and study of the spectrum. The transmission spectra of Al₂O₃ and CNT nano additive have been shown in Fig.3.7 (A) and Fig.3.7 (B), respectively. The presence of a few peaks of interest has been leveled. These peaks confirm the presence of the C and O elements in fuel samples. The Al₂O₃ fuel consists of 54.73% C and 32.55% O by weight; the sample CNT fuel consists of 48.10% C and 30.96% O by weight.

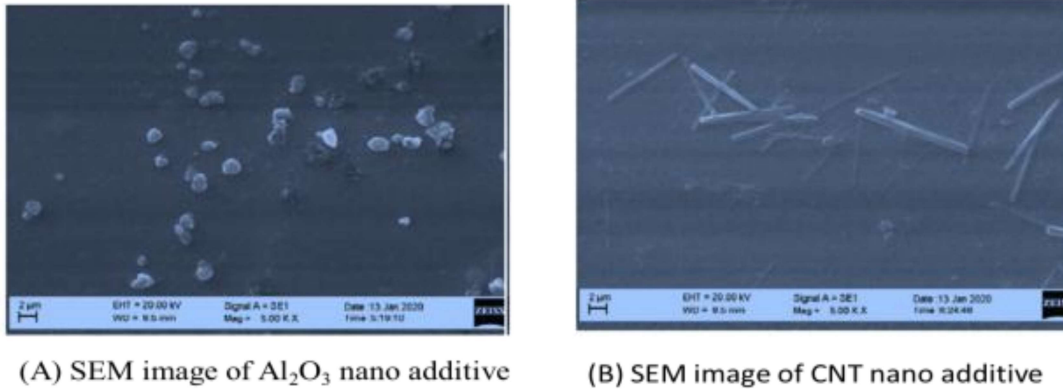


Fig.3.6 SEM image of (A) Al₂O₃ nano additive (B) CNT nano additive

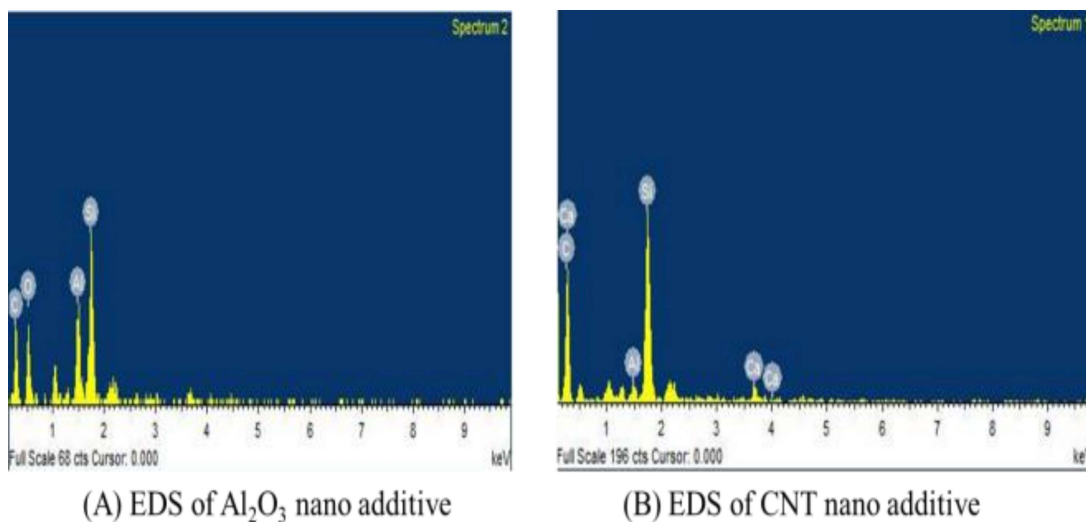


Fig.3.7 EDS image of (A) Al₂O₃ nano additive (B) CNT nano additive

3.4 Highlights

In this chapter, the various fuel samples are prepared for investigation, and their thermo-physical properties are measured using multiple scientific instruments. A single-step transesterification process designs the OPB and SOB biodiesel. Various fuel samples are prepared using OPB and SOB biodiesel with water emulsification and incorporate Al₂O₃ and CNT nano additives. The density, kinematic viscosity, lower heating value, flash point, and fire point of prepared fuel samples are measured and shown in tabular form. The SEM and EDS images observe the size and shape of Al₂O₃ and CNT nano additive. The following observation is taken from the detailed analysis.

- The density, calorific value, flash point, and fire point temperature of OPB-diesel blends are superior to SOB biodiesel blends fuel, but the kinematic viscosity of OPB-diesel blends is higher than SOB biodiesel blends.
- The properties of fuel samples are changed insignificantly due to the addition of nano additives, and Al_2O_3 incorporated fuel's properties are slightly superior to CNT incorporated fuel.
- In the SEM image of Al_2O_3 nano additive and CNT nano additive fuels, the configuration of the Al_2O_3 nano additive fuel is found spherical, and the configuration of CNT fuel is found cylindrical with less than 100 nm sizes.
- From the EDS analysis, it is observed that the Al_2O_3 incorporated sample consists of 54.73% C and 32.55% O by weight, and the CNT incorporated samples consist of 48.10% C and 30.96% O by weight.

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