



IIT ROORKEE



NPTEL ONLINE
CERTIFICATION COURSE

WASTE TO ENERGY CONVERSION

ENERGY PRODUCTION FROM WASTES THROUGH TRANSESTERIFICATION-1

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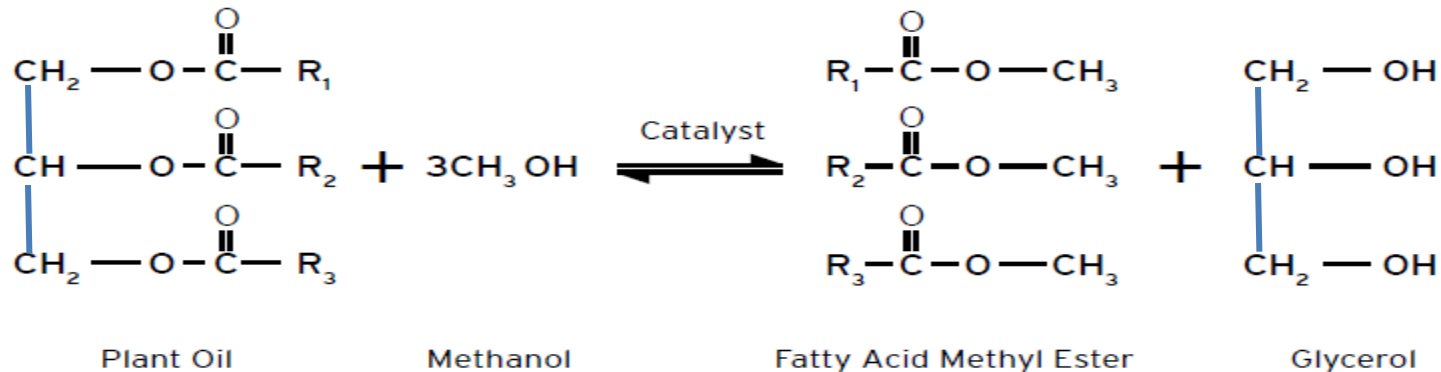


Contents

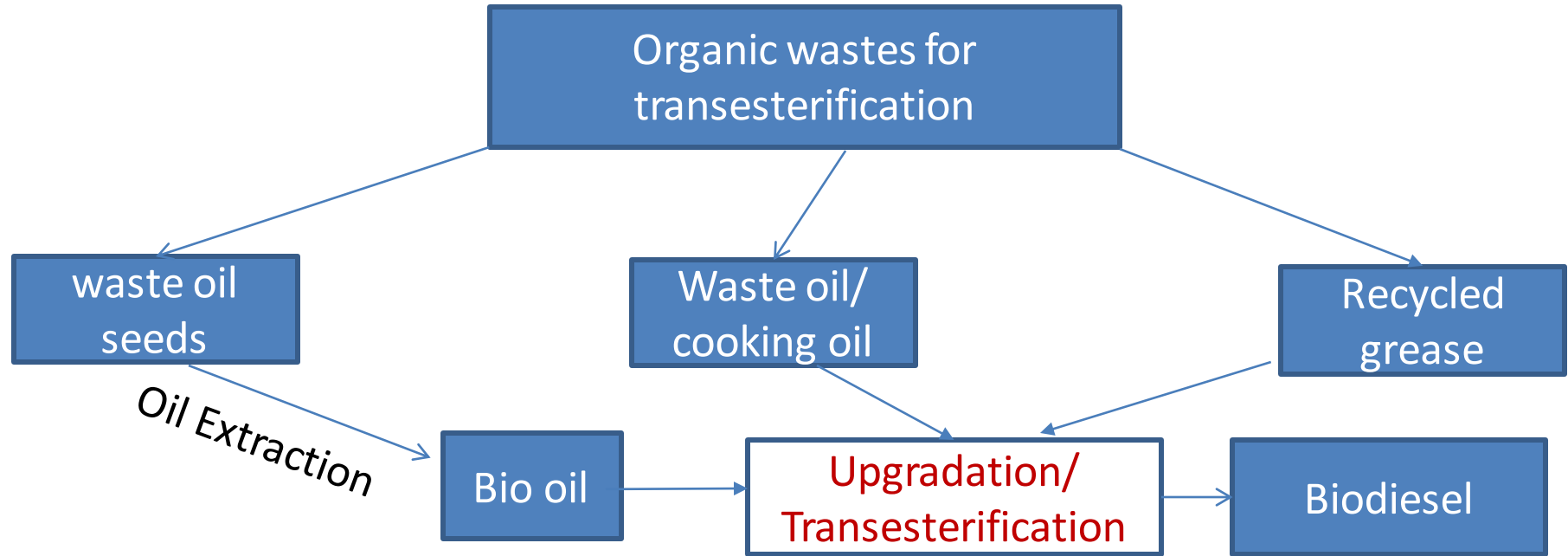
- What is transesterification ?
- Organic wastes for transesterification
- Production of bio oil from oil seeds and its major composition
- Need of upgradation of bio oil to bio diesel
- Bio diesel properties
- Upgradation flowsheets
- Steps for upgradation
- Biodiesel production from mixed waste pant oil /grease
- Combustion of bio oil/bio diesel in diesel engine

Transesterification process

During the process of transesterification, an alcohol (such as methanol) reacts with the triglyceride oils contained in plant oils, animal fats or recycled greases to form fatty acid alkyl esters (biodiesel) and glycerin. The reaction requires heat and a strong base catalyst such as sodium hydroxide or potassium hydroxide. The simplified chemical reaction is shown below

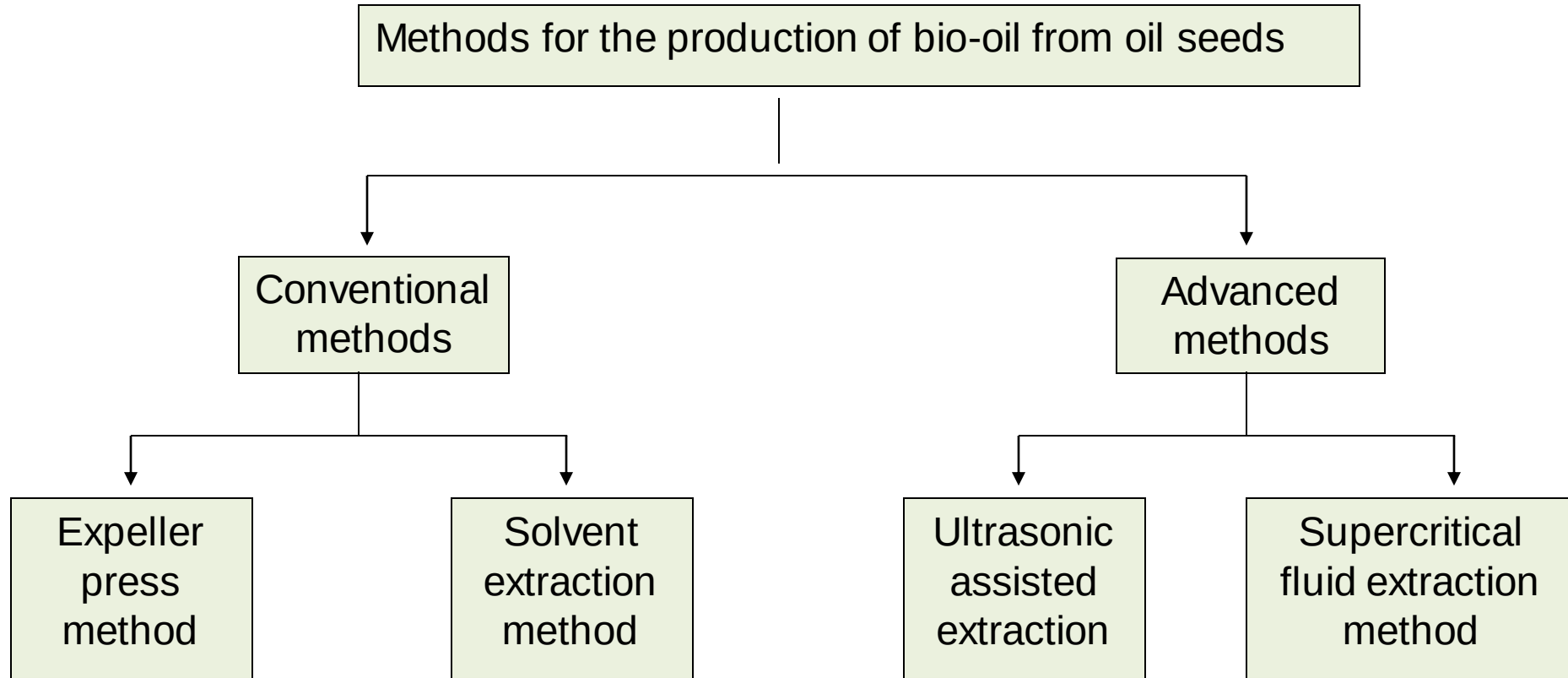


Organic wastes for transesterification



Other routes for energy production are: Incineration, gasification, pyrolysis and anaerobic digestion

Production of bio-oil from oil seeds



Various types of systems for bio-oil extraction



Oil Press



Solvent Extraction

Factors affecting oil extraction

- Type of solvent (hexane , n-heptane, ...)
- Biomass to solvent ratio
- Temperature
- Extraction method
- Extraction time
- Moisture content
- Particle size and shape

Comparison of various lipid extraction processes

Process	Advantages	Disadvantages
Oil press	Simple to use; No solvent required	Large biomass requirement; Slow
Solvent extraction	Solvent is expensive Solvent is recoverable /reproducible	Large solvent requirement; Expensive solvent recovery; flammable/ toxic
Supercritical fluid extraction	Solvent is non-toxic and non-flammable Operation is simple	Extraction of polar analyses from biomass is difficult Limited interaction between supercritical CO ₂ and biomass
Ultrasonic assisted extraction	Less extraction time Less solvent requirement Good penetration of solvent into cell, More release of cell contents	Scale up is not easy Power requirement is very high

Common fatty acids

Acid name	Elementary Formula	Structure	Melting point (°C)
Saturated fatty acids			
Lauric	$C_{12}H_{24}O_2$	$CH_3(CH_2)_{10}COOH$	44
Myristic	$C_{14}H_{28}O_2$	$CH_3(CH_2)_{12}COOH$	52
Palmitic	$C_{16}H_{32}O_2$	$CH_3(CH_2)_{14}COOH$	63
Stearic	$C_{18}H_{36}O_2$	$CH_3(CH_2)_{16}COOH$	69.5
Unsaturated fatty acids			
Oleic	$C_{18}H_{34}O_2$	$CH_3(CH_2)_7CH=CH-(CH_2)_7COOH$	+16
Linoleic	$C_{18}H_{32}O_2$	$CH_3(CH_2)_4(CH=CHCH_2)_2(CH_2)_6COOH$	-5
Linolenic	$C_{18}H_{30}O_2$	$CH_3(CH_2)_4(CH=CHCH_2)_3(CH_2)_3COOH$	-11
Arachidonic	$C_{20}H_{32}O_2$	$CH_3(CH_2)_4(CH=CHCH_2)_4(CH_2)_2COOH$	-50



Why upgradation

- Plant oil is much more viscous (thicker) than conventional diesel fuel. It is 11 to 17 times thicker.
- Plant oil also has very different chemical properties and combustion characteristics to those of conventional diesel fuel.
- If the fuel is too thick it will not atomize properly when the fuel injectors spray it into the combustion chamber and it will not combust properly – the injectors may get coked up, leading to poor performance, higher exhaust emissions and reduced engine life.
- The waste oil/ cooking oil and recycled grease loss their properties and require recycling and reuse.
- Transesterification improves the quality of these feedstocks and imparts fuel properties (Bio diesel)



Biodiesel

- Biodiesel is a mixture of fatty acid alkyl esters. It is non hazardous, nontoxic and biodegradable, and it reduces air pollutants such as particulates, carbon monoxide, hydrocarbons and air toxins.
- It burns more efficiently than petroleum diesel, and its higher lubricity can reduce engine wear, prolonging its lifetime.
- It can be used as a fuel for vehicles in its pure form, but it is usually used as a petroleum diesel **blend**. The most common use of biodiesel is as B20 (20% biodiesel, 80% diesel) and B2 (2% biodiesel, 98% diesel) or B1 (1% biodiesel, 99% diesel). Pure biodiesel requires special management in cold climates.
- The use of these blends requires no engine modifications.
- Due to slightly less energy density than petroleum diesel, the fuel economy tends to fall 7% for every 10% biodiesel in a fuel blend. High viscosity and flash point needs upgradation.



Important properties of biodiesel

- **Ash Percentage**-Ash is a measure of the amount of metals contained in the fuel.
- **Density** The weight per unit volume. Oils that are denser contain more energy. For example, gasoline and diesel fuels give comparable energy by weight, but diesel is denser and hence gives more energy per liter.
- **Cloud Point** The temperature at which an oil starts to solidify. While operating an engine at temperatures below an oil's cloud point, heating will be necessary in order to avoid waxing of the fuel.
- **Pour Point** refers to the temperature at which the oil in solid form starts to melt or pour. In cases where the temperatures fall below the melt point, the entire fuel system including all fuel lines and fuel tank will need to be heated.



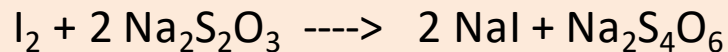
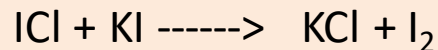
- **Cetane Number** A relative measure of the interval between the beginning of injection and autoignition of the fuel. The higher the cetane number, the shorter the delay interval and the greater its combustibility.
- Cetane number of cetane ($n\text{-C}_{16}\text{H}_{34}$) = 100 ;
 1-methylnaphthalene = 0 ;
 isocetane = 15
- Cetane number is measured by burning the fuel in a Cooperative Fuel Research (CFR) engine, under standard test conditions. A hand-wheel is used to increase the compression ratio (and therefore the peak pressure within the cylinder) of the engine until the time between fuel injection and ignition is 2.407ms.
- The resulting cetane number is then calculated by determining which mixture of cetane (hexadecane) and isocetane (2,2,4,4,6,8,8-heptamethylnonane) will result in the same ignition delay.

Important properties of biodiesel

- **Flash Point** The flash point temperature of fuel is the minimum temperature at which the fuel will ignite (flash) on application of an ignition source. Flash point varies inversely with the fuel's volatility. Minimum flash point temperatures are required for proper safety and handling of fuel.
- There are two basic types of flash point measurement: **open cup** and **closed cup**.
- In open cup flash point varies with the height of the flame above the liquid surface and, at sufficient height, the measured flash point temperature coincides with the fire point.
- In closed cup systems the cups are sealed with a lid through which the ignition source can be introduced. Closed cup testers normally give lower values for the flash point than open cup (typically 5–10 °C lower) and are a better approximation to the temperature at which the vapour pressure reaches the lower flammable limit.

- **Heating Value** is the amount of heating energy released by the combustion of a unit value of fuels. It depends on C, H and O content in the fuel.
- **Iodine Value** The amount of iodine, measured in grams, absorbed by 100 ml of a given oil. The degree of saturation is indicated by the Iodine Value of the oil.

The sample is treated with an excess of iodine monobromide (IBr) or iodine monochloride (ICl) solution in glacial acetic acid. Unreacted iodine monobromide (or monochloride) is then allowed to react with KI, converting it to iodine, whose concentration is determined by titration with sodium thiosulphate.



Important properties of biodiesel

- **Potassium Percentage.** The percentage, by weight, of potassium in the fuel.
- **Sulphur Percentage.** The percentage, by weight, of sulfur in the fuel. Sulfur content is limited by law to very small percentages for diesel fuel used in on-road applications.

Methods sulphur for detection:

- ✓ Colourimetric method (barium sulphate precipitation)
- ✓ Wickbond combustion method
- ✓ X-ray fluorescence
- ✓ ICP-MS

- **Viscosity** refers to the thickness of the oil, and is determined by measuring the amount of time taken for a given measure of oil to pass through an orifice of a specified size.

When liquid flows through tubes, $\eta = \frac{\pi r^4 P t}{8 V L}$ (Poiseuille's equation) Or $\eta = K P t \rightarrow \eta \propto K m t$

Thus, ratio of viscosity coefficient of a known and experimental sample = $\frac{\eta}{\eta_r} = \frac{m t}{m_r t_r}$

Where η is called the viscosity coefficient, t is the time of flow of liquid, V is the volume of the liquid, P is the hydrostatic pressure, and L is the distance travelled by the liquid during time t , r is radius of the tube, m_r is mass of reference liquid

Viscosity can be measured using a viscometer. The different types of viscometer are as follows:

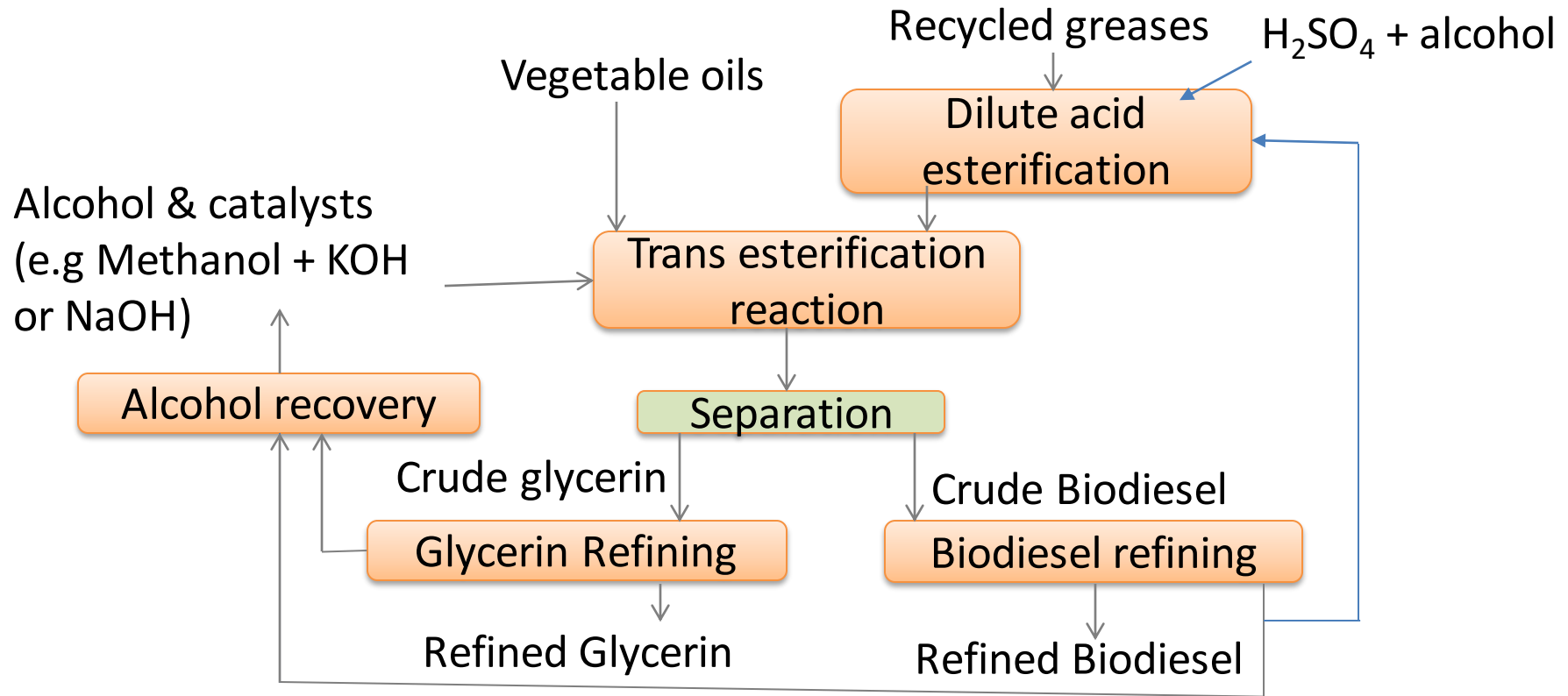
- | | |
|-----------------------------|---------------------------------|
| ✓ Ostwald viscometer | ✓ Oscillating piston viscometer |
| ✓ Falling sphere viscometer | ✓ Vibrational viscometers |
| ✓ Falling piston viscometer | ✓ Rotational viscometers |
| | ✓ Bubble viscometer |



Comparison of properties of biodiesel from different vegetable oils

Properties	Diesel	Soybean oil	Biodiesel from Soybean oil	Babassu oil	Biodiesel from Babassu oil
Kinematic viscosity at 38 °C (mm ² /sec)	3.06	32.6	4.5	30.3	3.6
Cetane no.	50	37.9	45	38	63
Heating value, MJ/L	43.8	39.6	33.5	-	31.8
Cloud point °C	-	-3.9	1	20	4
Pour point °C	-16	-12.2	-7	-	-
Flash point °C	76	254	178	150	127
Density Kg/L	0.855	0.9138	0.885	0.946	0.875

Generalized flowsheet for biodiesel production from various feedstocks



- The complete process for the production of methyl ester from plant oil and other feedstocks therefore involves basically five steps:
 - Acid esterification,
 - Transesterification,
 - Methanol recovery,
 - Biodiesel refining,
 - Glycerin refining.

Thanks...

