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WASTE TO WHEELS: TRANSFORMING ANIMAL FATS INTO BIODIESEL

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The growing demand for energy, depletion of fossil fuels and increasing environmental concerns have intensified the search for renewable fuels. Biodiesel, produced from biological oils and fats, is a promising alternative to conventional diesel.

Edible vegetable oils are widely used for biodiesel production, but their use for fuel raises concerns about food security, land use and food–fuel competition. This has increased interest in non-edible and waste-derived feedstocks, including animal fats.

Animal fat generated during slaughtering and meat processing is rich in triglycerides that can be converted into fatty acid methyl esters (FAME), the major components of biodiesel. Its recovery can therefore convert an underutilized slaughterhouse by-product into renewable fuel while supporting sustainable waste management.

Why Animal Fat?

Animal fats obtained from slaughterhouses and meat-processing industries include beef tallow, poultry fat and other rendered fats. Their use as biodiesel feedstocks offers several advantages:

- **Low-cost feedstock:** Animal fat can be less expensive than refined edible oils.
- **Waste utilization:** It provides a productive use for slaughterhouse by-products.
- **Reduced food competition:** It avoids diverting edible oils towards fuel production.
- **Energy recovery:** Lipid-rich animal fat can be converted into renewable fuel.
- **Resource recovery:** Waste material is transformed into a value-added product.
- **Circular bioeconomy:** It connects livestock production with renewable energy generation (Binhweel *et al.*, 2023).

From Fat to Fuel

Biodiesel production from animal fat generally involves fat recovery, purification, pretreatment and conversion into fatty acid methyl esters.

Fat Recovery and Pretreatment

Animal fat collected from slaughterhouses may contain water, proteins, tissue particles and other impurities. Rendering, filtration and moisture removal are therefore important for obtaining a suitable lipid fraction.

The free fatty acid (FFA) content is particularly important. Animal fats with high FFA levels may require pretreatment before alkaline transesterification because FFAs can react with alkaline catalysts and form soaps, reducing biodiesel recovery.

Transesterification

Transesterification is one of the most commonly used methods for biodiesel production. During this process, triglycerides present in animal fat react with an alcohol, generally methanol, in the presence of a catalyst.

The main products are:

- Fatty acid methyl esters (biodiesel)
- Glycerol

The efficiency of conversion depends on several factors:

- Alcohol-to-fat ratio
- Catalyst concentration
- Reaction temperature
- Reaction time
- Moisture content
- Free fatty acid concentration

Other approaches, including dilution, micro-emulsification and advanced conversion technologies, have also been investigated for improving the utilization of waste oils and animal fats (Xie *et al.*, 2026).

Role of Catalysts

Catalysts play an important role in improving the efficiency of biodiesel production. Several catalytic systems have been investigated for animal-fat feedstocks.

Homogeneous catalysts: Sodium hydroxide (NaOH) and potassium hydroxide (KOH) are commonly used because of their effective catalytic activity. However, high FFA and moisture contents can promote soap formation and complicate product separation.

Heterogeneous catalysts: Solid catalysts such as calcium oxide and modified metal oxides can be separated from the reaction mixture and may offer opportunities for catalyst recovery and reuse.

Enzymatic catalysts: Lipases can catalyse biodiesel production under relatively mild conditions and can reduce some unwanted side reactions. However, enzyme cost and operational requirements remain important considerations (Aslam *et al.*, 2026).

What Makes Animal-Fat Biodiesel Promising?

Animal-fat biodiesel possesses several characteristics that make it attractive as a renewable fuel:

- **High cetane number:** Supports favourable ignition characteristics.
- **Good oxidative stability:** Higher saturated fatty acid content can improve resistance to oxidation.
- **High energy content:** Animal fats are energy-dense lipid sources.
- **Waste reduction:** Conversion into fuel reduces the quantity of fat requiring disposal.
- **Renewable origin:** The feedstock is obtained from biological sources.

Biodiesel production from waste oils and animal fats can simultaneously address energy requirements and waste-management concerns. It also provides an opportunity to reduce dependence on fossil fuels while recovering value from materials generated by the food and livestock industries (Singh *et al.*, 2026).

Challenges in Animal-Fat Biodiesel Production

However, several factors can limit the large-scale production and use of animal-fat biodiesel:

- **High FFA content:** May require additional pretreatment before transesterification.

- **Moisture and impurities:** Can interfere with the conversion process.
- **Feedstock variability:** Fat composition can differ according to animal species, tissue source and processing conditions.
- **Cold-flow limitations:** High saturated fatty acid content can increase the melting point of biodiesel.
- **Processing cost:** Collection, rendering, pretreatment and purification can increase overall production costs.
- **Fuel quality:** Maintaining consistent biodiesel quality requires proper processing and effective quality control.

Efficient feedstock management and economical processing technologies are therefore essential for successful large-scale production.

Opportunities for Sustainable Production

The future development of animal-fat biodiesel can focus on improving processing efficiency, reducing costs and integrating biodiesel production with broader waste-management systems.

Improved Pretreatment: Efficient pretreatment methods can reduce moisture, impurities and free fatty acids, allowing low-quality animal fats to be used more effectively.

Low-Cost Catalysts: The development of reusable, efficient and waste-derived catalysts can reduce production costs while improving the sustainability of the process.

Integrated Waste Management

An integrated approach to slaughterhouse waste management can maximize the value of different by-products through applications such as:

- Biodiesel production
- Biogas generation
- Fertilizer production
- Protein recovery
- Other value-added products

Sustainable Supply Chains

Efficient collection, transportation, processing and distribution systems are important for maintaining a reliable supply of animal fat. Supply-chain optimization can improve economic performance and help manage uncertainties related to feedstock availability, processing capacity and market demand (Sarkar *et al.*, 2025).

Conclusion

Animal fat generated from slaughterhouses represents a valuable resource for sustainable biodiesel production. Its utilization can reduce waste-disposal problems, minimize dependence on edible oils and support renewable energy generation. Although feedstock quality, pretreatment and production costs remain important challenges, advances in catalysts, processing technologies and supply-chain management are improving its potential. Converting animal fat into biodiesel can therefore provide a practical link between livestock production, waste valorization and the circular bioeconomy.

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