



Waste-to-fuel: Biodiesel Production from Watermelon Seed Oil Using Sustainable CaO Nano Catalyst

Srilekshmi Muraleedharan^{1*}, Naveen S. Francis² and Beula Chandrika²

¹School of Engineering of Matter, Transport and Energy, Arizona State University, Tempe, USA

²Department of Chemical Engineering, Government Engineering College, Kozhikode, KL, India

Received: 16.03.2026 Accepted: 20.04.2026 Published: 30.06.2026

*srilekshnim@gmail.com



ABSTRACT

The increasing demand for sustainable energy and the depletion of fossil fuel reserves have intensified the search for viable alternative fuels. Biodiesel has gained significant attention due to its renewable nature and compatibility with existing diesel engines. In this study, watermelon seed oil, a non-edible and underutilized feedstock, was investigated for biodiesel production via transesterification using a low-cost CaO-based nano-catalyst derived from waste eggshells. The catalyst, rich in calcium oxide, was synthesized and characterized using FTIR, SEM, and XRD techniques to evaluate its structural and morphological properties. The transesterification process parameters, including catalyst loading, methanol-to-oil molar ratio, and reaction time, were systematically optimized. Under optimal conditions (3 wt% catalyst, 6:1 methanol-to-oil ratio, 4 hours), a maximum biodiesel yield of 99.4% was achieved. The produced biodiesel was evaluated for key fuel properties, including flash point (132 °C) and fire point (142 °C), confirming its suitability as a diesel substitute. The predominant fatty acid composition, mainly linoleic acid along with oleic, palmitic, and stearic acids, contributes to favorable fuel characteristics. This study demonstrates a sustainable approach by integrating waste-derived nano-catalysts with non-edible oil feedstock, thereby reducing production cost and environmental impact. The use of watermelon seed oil combined with eggshell-derived CaO nano-catalyst highlights a novel and economically viable pathway for biodiesel production.

Keywords: Bio-diesel; Watermelon seed oil; Nano-catalyst.

1. INTRODUCTION

In the past few decades, intensification in the search for renewable resources has taken a huge rise due to faster depletion of fossil fuels as well as energy security (Shafiee and Topal, 2009). The major consumption of world's energy is met by petroleum, natural gas and coal. Due to the faster depletion of these energy resources, a necessity has arisen to find alternative sources of energy. Biodiesel has turned out to be a promising fuel due to its less polluting nature and absence of sulphur. The life of catalytic converters can be extended in the absence of Sulphur. Biodiesel can be directly used in diesel engines without extensive modification (Mohite and Maji, 2020).

The edible vegetable oil has been gaining attention widely and seems to be a greater alternative to diesel fuel (Gui *et al.* 2008; Han *et al.* 2022; Sastry *et al.* 2011). The excellent lubrication and storage easiness makes it a really suitable purpose. Research has been carried out for decades on the effective conversion of edible oils to biodiesel (Bora *et al.* 2022; Encinar *et al.* 2011; Han *et al.* 2022). For the economical production of biodiesel, edible oil with a lesser amount of free fatty acid content (Bora *et al.* 2022; Chang *et al.* 2021; Encinar *et al.* 2011; Han *et al.* 2022; Javidialesaadi and Raeissi, 2013). The caloric value of biodiesel was found to be in

agreement with commercial diesel (Chang *et al.* 2021; Javidialesaadi and Raeissi, 2013). The production of biodiesel in situ generates high savings on foreign exchange. Besides the advantages of biodiesel, the higher viscosity makes it unsuitable for direct utilization in diesel engines. The efficient use of biodiesel in diesel engines calls for the reduction in viscosity, which is achieved by pyrolysis, cracking, and transesterification. In the present work, biodiesel is synthesized by the transesterification process (Chang *et al.* 2021; Chen *et al.* 2012; Encinar *et al.* 2011; Javidialesaadi and Raeissi, 2013).

In the present study, watermelon seed oil is used to synthesize biodiesel. Watermelon seed oil is found to contain 10 % of stearic acid, 11% of palmitic acid, 15% of oleic acid and about 63% of linoleic acids (Angelova-Romova *et al.* 2019; Moaddabdoost and Safe, 2010; Rai *et al.* 2015). Conventionally, watermelon seeds were pressed to obtain oil. The seeds are first extracted from the casing of the seeds, which are dried and pressed to obtain oil. The iodine value and saponification value of watermelon seed oil are found to be 125 and 190, respectively (Angelova-Romova *et al.* 2019; Moaddabdoost and Safe, 2010).

Regeneration of waste materials has been an area of great focus for the past few decades for

researchers. Eggshell being a potential waste product, come from eggs, which are included in the daily diet in different countries (Laca *et al.* 2017). Various forms of egg products are available in the market, including frozen eggs, liquid eggs and dried eggs. Eggs are a higher source of protein -6%, essential minerals, vitamins including A and D, as well as unsaturated fatty acids-10%. The poultry industry has turned out to be one of the major sectors in the world food chain. The rigorous research has formulated some value-added products, including absorption of dyes, calcium phosphate bio-ceramics, and hydroxyapatite for implanted materials (Laca *et al.* 2017; Niju *et al.* 2014; Wei *et al.* 2009). Eggshell is regarded as the main source of calcium carbonate (95%) and has been widely used in the production of heterogeneous catalysts (Faridi and Arabhosseini, 2018). The regeneration of the catalyst is found to be quite easy after the calcination process and is utilized for the conversion of oil to biodiesel (Faridi and Arabhosseini, 2018; Goli and Sahu, 2018). Homogeneous catalysts are easy to remove after the production of biodiesel, which, in addition, doesn't produce wastewater in comparison with homogeneous catalysts (Pandit and Fulekar, 2017; Yaşar, 2019).

Although several studies have explored biodiesel production from various non-edible oils, limited and inconsistent research exists on the use of watermelon seed oil as a feedstock. In particular, there is insufficient systematic investigation on how process variables such as methanol-to-oil ratio, catalyst concentration, reaction temperature, and reaction time collectively influence biodiesel yield and quality from watermelon seed oil. Moreover, existing literature lacks standardized optimization approaches and comparative evaluation of fuel properties against ASTM/EN biodiesel standards. Therefore, a clear research gap exists in optimizing production conditions and critically assessing the fuel performance of watermelon seed oil-derived biodiesel to determine its viability as a sustainable alternative fuel. A detailed analysis of the biodiesel prepared from watermelon seed oil using egg shell as catalyst is presented in the paper. The parameters, including methanol to oil ratio, temperature and time, were optimized. Biodiesel was analysed for its calorific value, flash point, fire point and the use of gas chromatography and mass spectroscopy

2. MATERIALS AND METHODS

2.1 Materials

n-hexane, filter paper, water melon seed, egg shell, methanol

2.2 Methods

2.2.1 Extraction of Watermelon Seed Oil

10g of milled watermelon seed samples, wrapped in an extraction thimble, was inserted to Soxhlet chamber. 250ml of n-hexane was heated for about 4-6 hours at 60°C in round bottom flask. The solvent is evaporated into the extraction chamber on heating and rises up to the condenser, which then falls back after condensation as liquid, washing or dissolving the fat or oil in the sample loaded back to the round bottom flask and reflux is continued for 6 hours. After the removal of the wrapped sample, the watermelon seed oil was obtained in round bottom flask by evaporating the solvent in the extraction chamber. The wrapped samples were dried in a hot air oven at 105°C for 30 minutes, allowed to cool, and weighed. The solvent was drained in a container for reuse. The parameters, including specific gravity, density, acid value, free fatty acid, iodine value, and saponification value, were determined.

To improve the sustainability of the process, solvent recovery and waste minimization strategies were incorporated during biodiesel production. n-Hexane used for the extraction of watermelon seed oil was recovered after extraction through rotary evaporation and reused in subsequent extraction cycles to reduce solvent consumption and environmental impact.

2.2.2 Preparation of Egg Shell Catalyst

The unwanted materials in the eggshell waste were removed by washing it repeatedly in tap water, followed by rinsing in distilled water about 3-4 times. The cleaned egg shells were oven dried at about 100°C for approximately 24 hours, and then ground, crushed and sieved. The size of eggshell powder was fixed at 250 µm. The dried egg shell waste was calcined at 900°C in a muffle furnace under static air with a heating rate of 2.5°C/min for 2 hours. All calcined samples were kept in a desiccator to avoid reaction with carbon dioxide (CO₂) and humid air before use. The catalyst was analyzed by scanning electron microscopy (SEM), Fourier transform infrared spectroscopy (FTIR), and X-ray diffraction (XRD) spectrometer. Particle size distribution of the CaO nanoparticles was determined using image analysis of SEM micrographs / dynamic light scattering (DLS). The average particle size was found to be ~ a few nm to 0.5 µm, indicating the formation of nano-scale catalytic

particles suitable for enhanced surface reactivity in the transesterification process.

The heterogeneous CaO catalyst derived from calcined egg shell waste was filtered after reaction, washed, and reused in subsequent cycles to evaluate its stability and reusability.

2.2.3 Preparation of Bio-diesel

Synthesis of bio-diesel was done by transesterification. A round-bottom flask containing a mixture of oil, catalyst (2-5 wt%) and methanol was placed inside the oil bath with a condenser connected to it. The stirring speed was maintained at 600 rpm throughout the reaction. It was heated to a temperature of 65°C, for alcohol to vaporize. The reaction was performed to obtain the maximum yield, and the optimum conditions of biodiesel were determined by varying the process variables: methanol/oil ratio, reaction temperature and reaction time (Table 1). After the reaction, the solid catalyst was separated by filtration. The solution was transferred to a separation funnel for the layers to separate; the top layer holds the biodiesel product, and glycerol in the bottom layer. Flash point, fire point and calorific value were determined for bio-diesel.

Excess methanol used in the transesterification reaction was recovered where possible and recycled for further experimental runs. The glycerol by-product generated during biodiesel synthesis was separated, collected, and stored for potential downstream utilization, thereby minimizing waste disposal.

Table 1. Parameters of the production of bio-diesel

Sample	Ratio	Temperature °C	Time (hours)
Sample 1	3:1(60ml methanol:20ml oil)	60	3
Sample 2	3:1(60ml methanol:20ml oil)	60	4
Sample 3	3:1(60ml methanol:20ml oil)	65	3
Sample 4	3:1(60ml methanol:20ml oil)	65	4
Sample 5	6:1(60ml methanol:10ml oil)	60	3
Sample 6	6:1(60ml methanol:10ml oil)	60	4
Sample 7	6:1(60ml methanol:10ml oil)	65	3
Sample 8	6:1(60ml methanol:10ml oil)	65	4

All liquid wastes were collected in designated chemical waste containers and disposed of according to institutional laboratory safety and environmental regulations. These measures collectively ensured partial

waste valorization and reduced the environmental footprint of the biodiesel production process.

3. RESULTS AND DISCUSSION

About 160 g of oil was obtained from 600 g of watermelon seed after extraction using a Soxhlet extraction apparatus. The various parameters determined for oil are tabulated in Table 2. The specific gravity of biodiesel varies with fatty acid composition and glycerine content. A denser biodiesel has higher energy content and results in better mileage and increased power. Since the fatty acid content dictates the specific gravity, a denser vegetable oil processes into a denser biodiesel. Vegetable oils typically have a specific gravity from 0.903 to 0.921, depending on the fatty acid composition and temperature. Specific gravity of biodiesel ranges from 0.86 to 0.90 due to the presence of contaminants (soap, monoglycerides, diglycerides, etc.). Biodiesel containing methanol as a contaminant has a specific gravity 0.005 lower than methanol-free biodiesel.

Biodiesel was analyzed to determine flash point, fire point and calorific value.

Table 2. Parameters evaluated for watermelon seed oil

Parameter	Value
Specific gravity	0.925
Gravity	0.835g/cm ³
Acid value	0.312 mg KOH/g
Free fatty acid	0.156
Iodine value	1.9
Saponification value	184.01 mg KOH/g oil

The Fig. 1 shows the SEM image of CaO nanoparticles. The bright areas of the picture reveal high emission of secondary electrons due to the high surface-to-volume ratio in those areas. The SEM morphology revealed the agglomeration of CaO nanoparticles. It can be seen from the micrograph that the synthesized sample is composed of grains with no regular shape. The average grain size of CaO nanoparticles varies from a few nm to 0.5 microns. The interaction between nanoparticles with a large surface area and high surface energy results in agglomeration. Individual particles can be seen as nano-sized plate-like crystals, partially fused to form hard agglomerates. The presence of pores in the CaO microsphere would increase catalytic activity in biodiesel production by the transesterification reaction from oil.

The SEM micrographs of the CaO catalyst derived from calcined egg shells reveal an irregular and highly porous morphology with significant agglomeration of particles. The porous structure is advantageous as it increases the available surface area, thereby enhancing catalytic activity during transesterification. Quantitative particle size analysis was

performed using ImageJ software by measuring particles at different magnifications based on the SEM scale bar. The average grain size of the CaO particles was found to be in the range of approximately [50-200 nm], while agglomerated clusters extended up to the micron scale ($\approx 0.5 \mu\text{m}$).

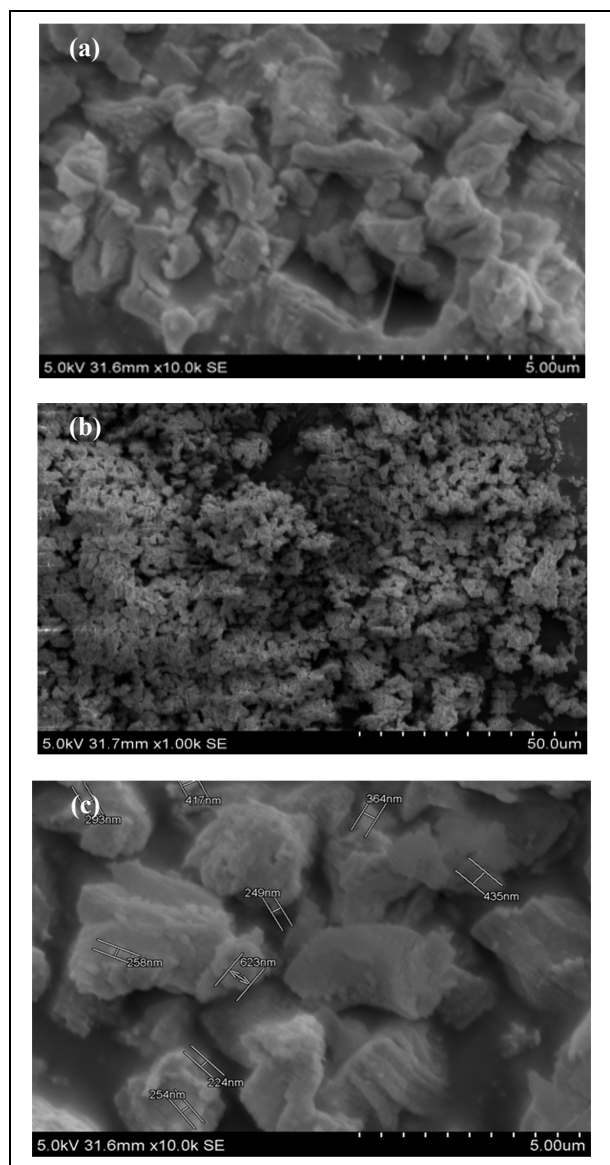


Fig. 1: (a), (b), (c): SEM micrograph of CaO nanoparticles derived from egg shell waste, showing a porous morphology and well-distributed nano-sized particles, which enhances catalytic surface area for biodiesel transesterification

A comparison of SEM images at different magnifications shows that smaller nano-sized crystallites tend to form larger aggregates due to high surface energy, which is typical for thermally derived CaO catalysts. Despite agglomeration, the presence of nano-scale primary particles contributes to increased active surface sites, which improves catalytic efficiency in biodiesel production.

Fig. 2 shows the FT-IR spectrum of the calcined egg shell-derived CaO catalyst. The broad absorption band around $3600\text{--}3400 \text{ cm}^{-1}$ corresponds to O–H stretching vibrations, indicating the presence of adsorbed moisture on the catalyst surface due to exposure to atmospheric humidity during handling. This surface hydroxylation can influence the basicity of the catalyst, which is important for transesterification activity.

The band observed around $1400\text{--}1500 \text{ cm}^{-1}$ is attributed to residual carbonate (CO_3^{2-}) species, suggesting partial re-carbonation of CaO upon exposure to air. The peak near 2350 cm^{-1} is associated with atmospheric CO_2 adsorption on the catalyst surface. The presence of these carbonate species indicates surface reactivity of CaO, which can still contribute to catalytic basic sites after activation.

A weak band around $700\text{--}750 \text{ cm}^{-1}$ corresponds to C–O stretching vibrations of carbonate groups, further confirming the presence of surface carbonate species. The strong and characteristic absorption band near $500\text{--}600 \text{ cm}^{-1}$ is assigned to Ca–O lattice vibrations, confirming the successful formation of CaO as the active catalytic phase. The FT-IR results confirm that the catalyst mainly consists of CaO with minor surface carbonate and hydroxyl species, which influence surface basicity and play a crucial role in enhancing the transesterification reaction efficiency.

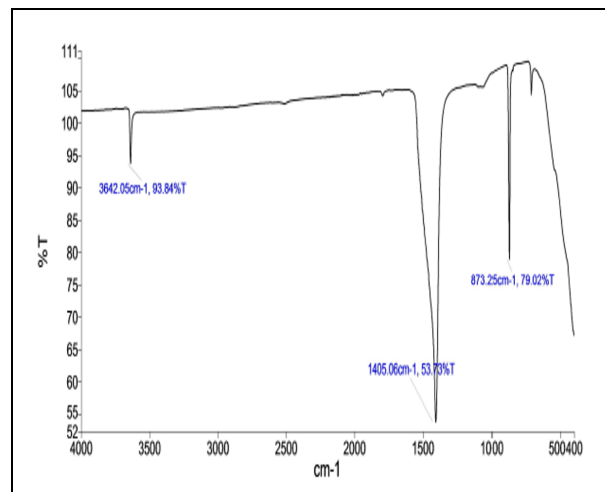


Fig. 2: FT-IR spectrum of calcined egg shell showing the characteristic absorption band of CaO, confirming successful conversion of calcium carbonate (CaCO_3) into active CaO catalyst after calcination

The result of XRD analysis of CaO catalyst derived from egg shell calcinated at 900°C for 4 hours is presented in Fig. 3. The diffraction peaks observed correspond to highly crystalline CaO, confirming successful formation of the active catalytic phase. The sharp and intense peaks indicate good crystallinity of the material, which is beneficial for catalytic activity in transesterification reactions.

Importantly, no significant peaks corresponding to calcium carbonate (CaCO_3) are observed in the XRD pattern, indicating complete thermal decomposition of CaCO_3 into CaO during calcination. This confirms that the calcination temperature of 900°C was sufficient to fully convert the precursor material into active CaO . The absence of secondary phases such as $\text{Ca}(\text{OH})_2$ or CaCO_3 also suggests high purity of the prepared catalyst, which contributes to its enhanced basicity and catalytic efficiency in biodiesel production.

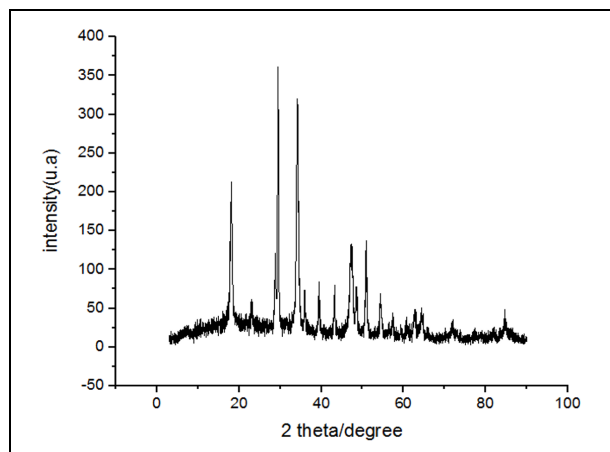


Fig. 3: XRD pattern of egg shell-derived catalyst (CaO), confirming the presence of crystalline CaO phases after calcination and indicating successful conversion of CaCO_3 into a highly crystalline catalytic material

XRD analysis shows the presence of formation of CaO on calcination, indicated by the presence of diffraction peaks. The CaO diffraction pattern is in accordance with the standards of JCPDS. Catalyst calcining contained mineral of calcite shows the incomplete decomposition of CaCO_3 to CaO with a cubic crystal structure (JCPDS-37-1497). The products obtained for various samples are tabulated in Table 3.

Table 3. Product obtained for various samples

Sample	Product
Sample 1	47 ml bio-diesel, 21 ml glycerol
Sample 2	49 ml bio-diesel, 16 ml glycerol
Sample 3	48 ml bio-diesel, 17 ml glycerol
Sample 4	50 ml bio-diesel, 13 ml glycerol
Sample 5	51 ml bio-diesel, 3 ml glycerol
Sample 6	54 ml bio-diesel, 5 ml glycerol
Sample 7	58 ml bio-diesel, 10 ml glycerol
Sample 8	60 ml bio-diesel, 9 ml glycerol

The biodiesel yield was calculated based on the ratio of the mass of purified biodiesel obtained to the initial mass of oil used in the transesterification reaction, expressed as a percentage (99.4%). All experiments were carried out in triplicate to ensure reproducibility, and the average values were reported.

The fuel properties of the produced biodiesel were evaluated to assess its suitability as an alternative diesel fuel. Flash point and fire point of biodiesel synthesized from watermelon seed oil were found to be 132°C and 142°C , respectively. The value of flash point is consistent with biodiesel (palm oil) but differs from neem oil biodiesel (120°C), as reported by which are higher than that of high-speed diesel ($60\text{--}80^\circ\text{C}$) (Ali *et al.* 2013).

The kinematic viscosity of the biodiesel was found to be $4.5 \text{ mm}^2/\text{s}$ at 40°C , which lies within the ASTM D6751 and EN 14214 acceptable range, indicating proper atomization characteristics during combustion. The density of the biodiesel was measured as 0.88 g/cm^3 , which is slightly higher than conventional diesel; however, it remains within the permissible limits for biodiesel fuels and does not significantly affect engine performance.

The calorific value of the biodiesel was determined to be 41 MJ/kg , which is lower than that of petroleum diesel due to the presence of oxygenated compounds in biodiesel. Despite this reduction, the energy content is sufficient for use in compression ignition engines with minimal modifications. The relatively higher flash point observed for the biodiesel compared to diesel enhances its safety during storage and handling. The measured fuel properties indicate that the watermelon seed oil-derived biodiesel exhibits characteristics comparable to conventional diesel fuel and satisfies major biodiesel quality standards.

4. CONCLUSIONS

Watermelon seed oil, due to its relatively high iodine value and saponification value, is a promising non-edible feedstock for biodiesel production. In this study, oil was extracted using *n*-hexane and subsequently used for transesterification, with process parameters optimized to maximize biodiesel yield. The utilization of waste egg shells as a heterogeneous catalyst source, primarily composed of CaO nanoparticles, as confirmed by SEM analysis, significantly enhanced the catalytic efficiency of the reaction. FTIR characterization confirmed the successful conversion of triglycerides into fatty acid methyl esters through the appearance and disappearance of characteristic functional group peaks. The optimized transesterification process achieved a biodiesel yield of 99.4%, indicating efficient conversion under the selected conditions. The produced biodiesel exhibited physicochemical properties comparable to conventional diesel fuel, with a notably higher flash point, indicating improved safety in storage and handling.

The observation that reaction time had minimal influence on yield beyond the optimal range suggests that equilibrium conversion was reached at relatively shorter durations, likely due to effective catalyst activity and

sufficient methanol availability; however, this requires further kinetic validation. Additionally, watermelon seed oil demonstrates potential industrial relevance not only in biofuel production but also in cosmetic and pharmaceutical applications due to its bioactive lipid composition. Future work will focus on engine performance testing, emission analysis, and long-term stability studies of the produced biodiesel to further validate its applicability as a sustainable alternative fuel.

COMPETING INTEREST STATEMENT

The authors declare that they have no competing interests regarding the manuscript.

DATA AVAILABILITY

All the data required to reproduce the work are presented in the manuscript.

ACKNOWLEDGMENT

The authors acknowledge the support of the Department of Chemical Engineering, GEC Kozhikode, for the facilities offered.

FUNDING

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

COPYRIGHT

This article is an open-access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).



REFERENCES

- Ali, M. H., Mashud, M., Rubel, M. R. and Ahmad, R. H., Biodiesel from Neem oil as an alternative fuel for Diesel engine, *Procedia Eng.*, 56, 625–630(2013). <https://doi.org/10.1016/j.proeng.2013.03.169>
- Angelova-Romova, M. Y., Simeonova, Z. B., Petkova, Z. Y., Antova, G. A. and Teneva, O. T., Lipid composition of watermelon seed oil, *Bulgarian Chem. Commun.*, 51, 268–272(2019). <https://doi.org/10.29333/ejosdr/7596>
- Bora, A. P., Konda, L. D., Pasupuleti, S. and Durbha, K. S., Synthesis of MgO/MgSO₄ nanocatalyst by thiourea–nitrate solution combustion for biodiesel production from waste cooking oil, *Renew. Energy*, 190, 474–486(2022). <https://doi.org/10.1016/j.renene.2022.03.127>
- Chang, M. Y., Chan, E. S. and Song, C. P., Biodiesel production catalysed by low-cost liquid enzyme Eversa® Transform 2.0: Effect of free fatty acid content on lipase methanol tolerance and kinetic model, *Fuel*, 283, 119266(2021). <https://doi.org/10.1016/j.fuel.2020.119266>
- Chen, L., Liu, T., Zhang, W., Chen, X. and Wang, J., Biodiesel production from algae oil high in free fatty acids by two-step catalytic conversion, *Biores. Technol.*, 111, 208–214(2012). <https://doi.org/10.1002/er.7882>
- Encinar, J. M., Sánchez, N., Martínez, G. and García, L., Study of biodiesel production from animal fats with high free fatty acid content, *Biores. Technol.*, 102(23), 10907–10914(2011). <https://doi.org/10.1016/j.biortech.2011.09.068>
- Faridi, H. and Arabhosseini, A., Application of eggshell wastes as valuable and utilizable products: A review, *Res. Agri. Eng.*, 64(2), 104–114(2018). <https://doi.org/10.17221/6/2017-RAE>
- Goli, J. and Sahu, O., Development of heterogeneous alkali catalyst from waste chicken eggshell for biodiesel production, *Renewable Energy*, 128, 142–154(2018). <https://doi.org/10.1016/j.renene.2018.05.048>
- Gui, M. M., Lee, K. T. and Bhatia, S., Feasibility of edible oil vs. non-edible oil vs. waste edible oil as biodiesel feedstock, *Energy*, 33(11), 1646–1653(2008). <https://doi.org/10.1016/j.fuel.2020.119266>
- Han, J., Jang, G., Kim, D. K., Kim, J. Y., Shin, J. W., Hwang, C., Piao, Y. and Kim, T., Dual-function electrochromic supercapacitor with graphene electrode, *Int. J. Energy Res.*, 46(8), 10822–10832(2022). <https://doi.org/10.1016/j.biortech.2012.02.033>
- Javidialesaadi, A. and Raeissi, S., Biodiesel production from high free fatty acid-content oils: experimental investigation of the pretreatment step, *APCBEE Procedia*, 5, 474–478(2013). <https://doi.org/10.1016/j.seppur.2014.12.016>
- Laca, A., Laca, A. and Díaz, M., Eggshell waste as catalyst: A review, *J. Environ. Manage.*, 197, 351–359(2017). <https://doi.org/10.1007/s11746-010-1546-5>
- Moaddabdoost, and Safe, K. A., Characteristics and composition of watermelon seed oil and solvent extraction parameters effects, *J. Am. Oil Chem. Soc.*, 87(6), 667–671(2010). <https://doi.org/10.1007/s11746-010-1546-5>

- Mohite, S. and Maji, S., Importance of energy audit in diesel engine fuelled with biodiesel blends: review and analysis, *Euro. J. Sustain. Develop. Res.*, 4(2), 0118(2020).
<https://doi.org/10.29333/ejosdr/7596>
- Niju, S., Meera, K. M., Begum, S. and Anantharaman, N., Modification of egg shell and its application in biodiesel production, *J. Saudi Chem. Soc.*, 18(5), 702–706(2014).
<https://doi.org/10.1016/j.jscs.2014.02.010>
- Pandit, P. R. and Fulekar, M. H., Egg shell waste as heterogeneous nanocatalyst for biodiesel production: optimized by response surface methodology, *J. Environ. Manage.*, 198, 319–329(2017).
<https://doi.org/10.1016/j.jscs.2014.02.010>
- Rai, A., Mohanty, B. and Bhargava, R., Modeling and response surface analysis of supercritical extraction of watermelon seed oil using carbon dioxide, *Sep. Purif. Technol.*, 141, 354–365(2015).
<https://doi.org/10.1016/j.seppur.2014.12.016>
- Sastry, S., Gupta, A. K. and Ramesh, P., Green technology for biodiesel formation, *Proce. Int. Conf. Workshop Emerging Trends Technol.*, 1340–1341(2011).
<https://doi.org/10.1145/1980022.1980319>
- Shafiee, S. and Topal, E., When will fossil fuel reserves be diminished? *Energy Policy*, 37(1), 181–189(2009).
<https://doi.org/10.1016/j.enpol.2008.08.016>
- Wei, Z., Xu, C. and Li, B., Application of waste eggshell as low-cost solid catalyst for biodiesel production, *Biores. Technol.*, 100(11), 2883–2885(2009).
<https://doi.org/10.1016/j.biortech.2008.12.039>
- Yaşar, F., Biodiesel production via waste eggshell as a low-cost heterogeneous catalyst: Its effects on some critical fuel properties and comparison with CaO, *Fuel*, 255, 115828(2019).
<https://doi.org/10.1016/j.fuel.2019.115828>