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Development of empirical correlations for density and viscosity estimation of ternary biodiesel blends
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Abstract

This study aims to investigate the density and viscosity of ternary biodiesel blends. Fuel density and viscosity play an important role in the fuel injection system, flame propagation, and combustion process in compression ignition engine. The density and viscosity of biodiesel are higher than high-speed diesel which is an implication in the commercialization of biodiesel. In the present study, palm oil has been used for the production of biodiesel through the ultrasound-assisted transesterification process. Three different types of fuel additives including butanol, dimethyl carbonate, and plastic oil have been used for the preparation of nine ternary biodiesel blends. The density and viscosity of individual fuels and ternary biodiesel were measured experimentally in a temperature range of 281.51 K–348.15 K. For the prediction of density and viscosity of ternary biodiesel blends, four density and viscosity models were developed. The prediction accuracy of these developed models was assessed by a statistical tool absolute percentage error (APE). Newly proposed exponential regression models predicted well compared to experimental data for density and viscosity values with high regression coefficient 0.9995 and 0.9841 and lower mean absolute percentage of error 0.012 % and – 0.516 % at (348.15 K) temperature respectively. These correlations are significant for the automobile industry in developing fuel pipeline and transport equipment where additives would be present in diesel-biodiesel fuel blends. © 2021 Elsevier Ltd

Author Keywords
Butanol; Density; Dimethyl carbonate; Palm biodiesel; Ternary blends; Viscosity; Waste plastic oil

Index Keywords
Density (specific gravity), Diesel engines, Fuel additives, Ignition, Regression analysis, Viscosity, Waste incineration; Bio-diesel blends, Density, Density estimation, Dimethyl carbonate, Empirical correlations, Fuel density, Palm biodiesels, Ternary blends, Viscosity estimation, Waste plastic oil; Biodiesel; additive, biofuel, combustion, empirical analysis, engine, ultrasonics

References

- Mo, J., Tang, C., Li, J., Guan, L., Huang, Z.
  Experimental investigation on the effect of n-butanol blending on spray characteristics of soybean biodiesel in a common-rail fuel injection system

(2016) *Fuel*, 182, pp. 391-401.

- Das, M., Sarkar, M., Datta, A., Santra, A.K.
  Study on viscosity and surface tension properties of biodiesel-diesel blends and their effects on spray parameters for CI engines
  (2018) *Fuel*, 220, pp. 769-779.

- Gul, M., Masjuki, H.H., Kalam, M.A., Zulkifli, N.W.M., Mujtaba, M.A.
  A review: role of fatty acids composition in characterizing potential feedstock for sustainable green lubricants by advance transesterification process and its global as well as Pakistani prospective
  (2020) *BioEnergy Res.*, 13 (1), pp. 1-22.

- Gabriel, R., Vieira, W.T., Soletti, J.I., Ribeiro, L.M.O., Carvalho, S.H.V.
  Empirical modeling of different viscosity and density behavior of biodiesel from chichá (Sterculia striata) with diesel versus temperature variation
  (2020) *J. King Saud Univ. Sci.*, 32 (1), pp. 628-635.

- Mujtaba, M., Kalam, M., Masjuki, H., Gul, M., Soudagar, M.E.M., Ong, H.C., Ahmed, W., Yusoff, M.
  Comparative study of nanoparticles and alcoholic fuel additives-biodiesel-diesel blend for performance and emission improvements
  (2020) *Fuel*, 279.

- Mujtaba, M.A., Muk Cho, H., Masjuki, H.H., Kalam, M.A., Farooq, M., Soudagar, M.E.M., Gul, M., Syahir, A.Z.
  Effect of alcoholic and nano-particles additives on tribological properties of diesel–palm–sesame–biodiesel blends
  (2021) *Energy Rep.*, 7, pp. 1162-1171.

- Mujtaba, M., Masjuki, H., Kalam, M., Ong, H.C., Gul, M., Farooq, M., Soudagar, M.E.M., Yusoff, M.
  Ultrasound-assisted process optimization and tribological characteristics of biodiesel from palm-sesame oil via response surface methodology and extreme learning machine-Cuckoo search
  (2020) *Renew. Energy*, 158, pp. 202-214.

- Zhou, S., Liu, L., Wang, B., Xu, F., Sun, R.C.
  Biodiesel preparation from transesterification of glycerol trioleate catalyzed by basic ionic liquids
  (2012) *Chin. Chem. Lett.*, 23 (4), pp. 379-382.

- Amini, Z., Ilham, Z., Ong, H.C., Mazaheri, H., Chen, W.-H.
  State of the art and prospective of lipase-catalyzed transesterification reaction for biodiesel production
  (2017) *Energy Convers. Manag.*, 141, pp. 339-353.

- Arjanggi, R.D., Kansedo, J.
  Recent advancement and prospective of waste plastics as biodiesel additives: a review
  (2020) *J. Energy Inst.*, 93 (3), pp. 934-952.

- Tan, S.X., Lim, S., Ong, H.C., Pang, Y.L.
  State of the art review on development of ultrasound-assisted catalytic

transesterification process for biodiesel production
(2019) *Fuel*, 235, pp. 886-907.

- Xi, B., Jiang, Y., Li, M., Yang, Y., Huang, C.
Groundwater Pollution and its Risk in Solid Waste Disposal Site, Optimization of Solid Waste Conversion Process and Risk Control of Groundwater Pollution
(2016), pp. 75-104.
Springer

- Tang, Z., Huang, Q., Cheng, J., Yang, Y., Yang, J., Guo, W., Nie, Z., Jin, L.
Polybrominated diphenyl ethers in soils, sediments, and human hair in a plastic waste recycling area: a neglected heavily polluted area
(2014) *Environ. Sci. Technol.*, 48 (3), pp. 1508-1516.

- Geyer, R., Jambeck, J.R., Law, K.L.
Production, use, and fate of all plastics ever made
(2017) *Sci. Adv.*, 3 (7).

- Rochman, C.M., Browne, M.A., Halpern, B.S., Hentschel, B.T., Hoh, E., Karapanagioti, H.K., Rios-Mendoza, L.M., Thompson, R.C.
Classify plastic waste as hazardous
(2013) *Nature*, 494 (7436), pp. 169-171.

- Knothe, G., Krahl, J., Van Gerpen, J.
The Biodiesel Handbook
(2015), Elsevier

- Al-Salem, S., Lettieri, P., Baeyens, J.
The valorization of plastic solid waste (PSW) by primary to quaternary routes: from re-use to energy and chemicals
(2010) *Progr. Energy Combust. Sci.*, 36 (1), pp. 103-129.

- Damodharan, D., Sathiyagnanam, A.P., Rana, D., Kumar, B.R., Saravanan, S.
Combined influence of injection timing and EGR on combustion, performance and emissions of DI diesel engine fueled with neat waste plastic oil
(2018) *Energy Convers. Manag.*, 161, pp. 294-305.

- Mujtaba, M., Masjuki, H., Kalam, M., Noor, F., Farooq, M., Ong, H.C., Gul, M., Rizwanul Fattah, I.
Effect of additivized biodiesel blends on diesel engine performance, emission, tribological characteristics, and lubricant tribology
(2020) *Energies*, 13 (13), p. 3375.

- Razzaq, L., Mujtaba, M.A., Soudagar, M.E.M., Ahmed, W., Fayaz, H., Bashir, S., Fattah, I.M.R., El-Seesy, A.I.
Engine performance and emission characteristics of palm biodiesel blends with graphene oxide nanoplatelets and dimethyl carbonate additives
(2021) *J. Environ. Manag.*, 282.

- Mujtaba, M.A., Kalam, M.A., Masjuki, H.H., Soudagar, M.E.M., Khan, H.M., Fayaz, H., Farooq, M., Razzaq, L.
Effect of palm-sesame biodiesel fuels with alcoholic and nanoparticle additives on tribological characteristics of lubricating oil by four ball tribo-tester
(2021) *Alexandria Eng. J.*, 60 (5), pp. 4537-4546.

- Lapuerta, M., Rodríguez-Fernández, J., Fernández-Rodríguez, D., Patiño-Camino, R.
  Modeling viscosity of butanol and ethanol blends with diesel and biodiesel fuels
  (2017) *Fuel*, 199, pp. 332-338.

- Pratas, M.J., Freitas, S.V., Oliveira, M.B., Monteiro, S.C., Lima, Á.S., Coutinho, J.A.
  Fuels, Biodiesel density: experimental measurements and prediction models
  (2011) *Energy*, 25 (5), pp. 2333-2340.

- Gülüm, M., Bilgin, A.
  Two-dimensional surface models to predict the density of biodiesel-diesel-alcohol ternary blends
  (2021) *Energy Sources, Part A Recovery, Util. Environ. Eff.*, 43 (5), pp. 517-587.

- Razzaq, L., Farooq, M., Mujtaba, M., Sher, F., Farhan, M., Hassan, M.T., Soudagar, M.E.M., Imran, M.
  Modeling viscosity and density of ethanol-diesel-biodiesel ternary blends for sustainable environment
  (2020) *Sustainability*, 12 (12), p. 5186.

- Al-Hartomy, O.A., Mujtaba, M.A., Al-Ghamdi, A., Iqbal, J., Wageh, S.
  Combined effect of Phoenix dactylifera biodiesel and multiwalled carbon nanotube–titanium dioxide nanoparticles for modified diesel engines
  (2021) *Int. J. Environ. Sci. Technol.*, pp. 1-26.

- Gülüm, M., Bilgin, A.
  Measurements and empirical correlations in predicting biodiesel-diesel blends' viscosity and density
  (2017) *Fuel*, 199, pp. 567-577.

- Mishra, S., Bukkarapu, K.R., Krishnasamy, A.
  A composition based approach to predict density, viscosity and surface tension of biodiesel fuels
  (2021) *Fuel*, 285.

- Tesfa, B., Mishra, R., Gu, F., Powles, N.
  Prediction models for density and viscosity of biodiesel and their effects on fuel supply system in CI engines
  (2010) *Renew. Energy*, 35 (12), pp. 2752-2760.

- Soudagar, M.E.M., Banapurmath, N.R., Afzal, A., Hossain, N., Abbas, M.M., Haniffa, M.A.C.M., Naik, B., Mubarak, N.M.
  Study of diesel engine characteristics by adding nanosized zinc oxide and diethyl ether additives in Mahua biodiesel–diesel fuel blend
  (2020) *Sci. Rep.*, 10 (1).

- Ramírez-Verduzco, L.F., Rodríguez-Rodríguez, J.E., del Rayo Jaramillo-Jacob, A.
  Predicting cetane number, kinematic viscosity, density and higher heating value of biodiesel from its fatty acid methyl ester composition
  (2012) *Fuel*, 91 (1), pp. 102-111.

- Barabás, I., Todoruț, I.-A.
  Utilization of Biodiesel-Diesel-Ethanol Blends in CI Engine, Biodiesel-Quality, Emissions and By-Products
  (2011), IntechOpen

- Fan, J., Liu, Q., Song, F., Wang, X., Zhang, L.
  Experimental investigations on the liquid thermal conductivity of five saturated fatty acid methyl esters components of biodiesel
  (2018) *J. Chem. Therm.*, 125, pp. 50-55.

- Verduzco, L.F.R.
  Density and viscosity of biodiesel as a function of temperature: empirical models
  (2013) *Renew. Sustain. Energy Rev.*, 19, pp. 652-665.

- Veny, H., Baroutian, S., Aroua, M.K., Hasan, M., Raman, A.A., Sulaiman, N.M.N.
  Density of Jatropha curcas seed oil and its methyl esters: measurement and estimations
  (2009) *Int. J. Thermophys.*, 30 (2), pp. 529-541.

- Baroutian, S., Aroua, M.K., Raman, A.A., Sulaiman, N.M.N.
  Density of palm oil-based methyl ester
  (2008) *J. Chem. Eng. Data*, 53 (3), pp. 877-880.

- Anand, K., Ranjan, A., Mehta, P.S.
  Predicting the density of straight and processed vegetable oils from fatty acid composition
  (2010) *Energy Fuels*, 24 (5), pp. 3262-3266.

- Niculescu, R., Clenci, A., Iorga-Siman, V.
  Review on the use of diesel–Biodiesel–Alcohol blends in compression ignition engines
  (2019) *Energies*, 12 (7), p. 1194.

- Gulum, M., Bilgin, A.
  Measurement and prediction of density and viscosity of different diesel-vegetable oil binary blends, Scientific Journal of Riga Technical University
  (2019) *Environ. Clim. Technol.*, 23 (1), pp. 214-228.

- Gülüm, M., Onay, F.K., Bilgin, A.
  Measurement and estimation of densities of different biodiesel–diesel–alcohol ternary blends
  (2019) *Environ. Prog. Sustain. Energy*, 38 (6).

- Aminian, A., ZareNezhad, B.
  Accurate predicting the viscosity of biodiesels and blends using soft computing models
  (2018) *Renew. Energy*, 120, pp. 488-500.

- Barabás, I.
  Predicting the temperature dependent density of biodiesel–diesel–bioethanol blends
  (2013) *Fuel*, 109, pp. 563-574.

- Gülüm, M., Onay, F.K., Bilgin, A.
  Comparison of viscosity prediction capabilities of regression models and artificial neural networks
  (2018) *Energy*, 161, pp. 361-369.

- Barabás, I., Todorut, I.A.
  Fuels, Predicting the temperature dependent viscosity of biodiesel–diesel–bioethanol blends

(2011) *Energy*, 25 (12), pp. 5767-5774.

- Chavarria-Hernandez, J.C., Pacheco-Catalán, D.E.
  Predicting the kinematic viscosity of FAMEs and biodiesel: empirical models
  (2014) *Fuel*, 124, pp. 212-220.

- Allen, C.A., Watts, K., Ackman, R., Pegg, M.
  Predicting the viscosity of biodiesel fuels from their fatty acid ester composition
  (1999) *Fuel*, 78 (11), pp. 1319-1326.

- Pereira, E., Meirelles, A.J., Maximo, G.J.
  Predictive models for physical properties of fats, oils, and biodiesel fuels
  (2020) *Fluid Phase Equil.*, 508.

- Kaimal, V.K., Vijayabalan, P.
  A detailed study of combustion characteristics of a DI diesel engine using waste plastic oil and its blends
  (2015) *Energy Convers. Manag.*, 105, pp. 951-956.

- Kumar, S., Prakash, R., Murugan, S., Singh, R.K.
  Performance and emission analysis of blends of waste plastic oil obtained by catalytic pyrolysis of waste HDPE with diesel in a CI engine
  (2013) *Energy Convers. Manag.*, 74, pp. 323-331.

- Damodharan, D., Rajesh Kumar, B., Gopal, K., De Poures, M.V., Sethuramasamyraja, B.
  Utilization of waste plastic oil in diesel engines: a review
  (2019) *Rev. Environ. Sci. Biotechnol.*, 18 (4), pp. 681-697.

- Mani, M., Nagarajan, G., Sampath, S.
  Characterisation and effect of using waste plastic oil and diesel fuel blends in compression ignition engine
  (2011) *Energy*, 36 (1), pp. 212-219.

- Zheng, Y., Shadloo, M.S., Nasiri, H., Maleki, A., Karimipour, A., Tlili, I.
  Prediction of viscosity of biodiesel blends using various artificial model and comparison with empirical correlations
  (2020) *Renew. Energy*, 153, pp. 1296-1306.

- Yahya, S.I., Aghel, B.
  Estimation of kinematic viscosity of biodiesel-diesel blends: comparison among accuracy of intelligent and empirical paradigms
  (2021) *Renew. Energy*, 177, pp. 318-326.

- Milano, J., Ong, H.C., Masjuki, H.H., Silitonga, A.S., Chen, W.-H., Kusumo, F., Dharma, S., Sebayang, A.H.
  Optimization of biodiesel production by microwave irradiation-assisted transesterification for waste cooking oil-Calophyllum inophyllum oil via response surface methodology
  (2018) *Energy Convers. Manag.*, 158, pp. 400-415.

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