TABLE V
COMPOSITION OF FAME FROM GC ANALYSIS ON KOH CATALYST MASS 0.75% WT. OIL, STIRRING SPEED 300 RPM, REACTION TEMPERATURE 60ºC, MOLAR RATIO OF OIL:METHYL ACETATE = 1:6 AND REACTION TIME 1 HOUR

FAME (Fatty Acid Methyl Esters)	Composition (%)
Methyl Laurate	0.7736
Methyl Palmitate	67.4598
Methyl Oleate	5.6366
Methyl Linoleate	26.0750
Methyl Stearate	0.0549

GC chromatogram results for FAME resulting from triglyceride and methyl acetate interesterification reaction on the mass of catalyst KOH 0.75% wt. oil, stirring speed of 300 rpm, reaction temperature of 60ºC, molar ratio of oil: methyl acetate = 1:6, and reaction time of 1 hour are presented in Figure 6. The FAME composition, which is from triglyceride and methyl acetate interesterification reaction on the KOH catalyst mass is 0.75% wt oil, stirring speed 300 rpm, reaction temperature 60ºC, molar ratio of oil: methyl acetate = 1:6, and reaction time 1 hour are presented in Table V. The biggest FAME composition is methyl palmitate 67.4598% is according to the largest composition of palm oil namely palmitate acid.

IV. CONCLUSION

Stirring speed and type of catalyst are two factors that determine the success of the interesterification reaction between triglycerides and methyl acetate to produce methyl esters and triacetin. From the analysis and calculation results obtained the highest FAME yield of 57.30% at a reaction temperature of 60ºC, the molar ratio of palm oil: methyl acetate = 1: 6, reaction time 1 hour, KOH catalyst, stirring speed of 300 rpm, and catalyst mass 0.75% wt . oil. From the results of the ChemDraw software calculation. This research found that the KOH catalyst was superior to the NaOH catalyst from its ability to make the reactants more reactive and the energy kinetic and dipole moment higher than the NaOH catalyst. From the analysis results, biodiesel has an acid value of 0.3927 mg KOH/gr and meets ASTM D664 for a maximum acid value of 0.5 mg KOH/gr.

NOMENCLATURE

ρ	density	$grml^{-1}$
kA	the reaction rate constant	
A	factor collision frequency	
E	activation energy	$kJmol^{-1}$
R	ideal gas constant	$8{,}314\ Jmol^{-1}K^{-1}$
T	absolute temperature	K

ACKNOWLEDGMENT

The authors are grateful to the Department of Chemical Engineering and the Bioenergy Laboratory staff of the National Institute of Technology Malang, who have supported and provided research facilities.

REFERENCES

[1] R. M. Ali, M. R. Elkatory, and H. A. Hamad, "Highly active and stable magnetically recyclable $CuFe_2O_4$ as a heterogenous catalyst for efficient conversion of waste frying oil to biodiesel," *Fuel*, vol. 268, no. January, p. 117297, 2020, doi: 10.1016/j.fuel.2020.117297.

[2] L. Interrante *et al.*, "Interesterification of rapeseed oil catalysed by a low surface area tin (II) oxide heterogeneous catalyst," *Fuel Process. Technol.*, vol. 177, no. May, pp. 336–344, 2018.

[3] A. Kumar and S. Sharma, "An evaluation of multipurpose oil seed crop for industrial uses (Jatropha curcas L.): A review," *Ind. Crops Prod.*, vol. 28, no. 1, pp. 1–10, 2008, doi: 10.1016/j.indcrop.2008.01.001.

[4] J. Pullen and K. Saeed, "Investigation of the factors affecting the progress of base-catalyzed transesterification of rapeseed oil to biodiesel FAME," *Fuel Process. Technol.*, vol. 130, no. C, pp. 127–135, 2015, doi: 10.1016/j.fuproc.2014.09.013.

[5] A. Casas, M. J. Ramos, and Á. Pérez, "New trends in biodiesel production: Chemical interesterification of sunflower oil with methyl acetate," *Biomass and Bioenergy*, vol. 35, no. 5, pp. 1702–1709, 2011, doi: 10.1016/j.biombioe.2011.01.003.

[6] M. O. Ferreira, L. Cardozo Filho, C. Silva, and E. M. B. D. Sousa, "Glycerol as additive for fuels - A review," *Lat. Am. Appl. Res.*, vol. 44, no. 1, pp. 47–56, 2014.

[7] A. L. B. Nunes and F. Castilhos, "Chemical interesterification of soybean oil and methyl acetate to FAME using CaO as catalyst," *Fuel*, vol. 267, no. October 2019, p. 117264, 2020, doi: 10.1016/j.fuel.2020.117264.

[8] Z. H. Li, P. H. Lin, J. C. S. Wu, Y. T. Huang, K. S. Lin, and K. C. W. Wu, "A stirring packed-bed reactor to enhance the esterification-transesterification in biodiesel production by lowering mass-transfer resistance," *Chem. Eng. J.*, vol. 234, pp. 9–15, 2013, doi: 10.1016/j.cej.2013.08.053.

[9] R. D. Kusumaningtyas, R. Pristiyani, and H. Dewajani, "A new route of biodiesel production through chemical interesterification of jatropha oil using ethyl acetate," *Int. J. ChemTech Res.*, vol. 9, no. 6, pp. 627–634, 2016.

[10] S. Chuepeng and C. Komintarachat, "Interesterification optimization of waste cooking oil and ethyl acetate over homogeneous catalyst for biofuel production with engine validation," *Appl. Energy*, vol. 232, no. July, pp. 728–739, 2018, doi: 10.1016/j.apenergy.2018.09.085.

[11] H. C. Nguyen, S. H. Liang, S. S. Chen, C. H. Su, J. H. Lin, and C. C. Chien, "Enzymatic production of biodiesel from insect fat using methyl acetate as an acyl acceptor: Optimization by using response surface methodology," *Energy Convers. Manag.*, vol. 158, no. December 2017, pp. 168–175, 2018.

[12] G. R. Tavares, J. E. Gonçalves, W. D. dos Santos, and C. da Silva, "Enzymatic interesterification of crambe oil assisted by ultrasound," *Ind. Crops Prod.*, vol. 97, pp. 218–223, 2017, doi: 10.1016/j.indcrop.2016.12.022.

[13] N. Postaue, C. P. Trentini, B. T. F. de Mello, L. Cardozo-Filho, and C. da Silva, "Continuous catalyst-free interesterification of crambe oil using methyl acetate under pressurized conditions," *Energy Convers. Manag.*, vol. 187, no. March, pp. 398–406, 2019, doi: 10.1016/j.enconman.2019.03.046.

[14] Y. Tian, J. Xiang, C. C. Verni, and L. Soh, "Fatty acid methyl ester production via ferric sulfate catalyzed interesterification," *Biomass and Bioenergy*, vol. 115, no. November 2017, pp. 82–87, 2018.

[15] J. dos Santos Ribeiro, D. Celante, S. S. Simões, M. M. Bassaco, C. da Silva, and F. de Castilhos, "Efficiency of heterogeneous catalysts in interesterification reaction from macaw oil (Acrocomia aculeata) and methyl acetate," *Fuel*, vol. 200, pp. 499–505, 2017.

[16] E. D. Daryono and E. J. Sinaga, "Rapid in situ transesterification of Papaya seeds to biodiesel with the aid of co-solvent," *Int. J. Renew. Energy Res.*, vol. 7, no. 1, 2017.

[17] J. Shao and F. Agblevor, "New Rapid Method for the Determination of Total Acid Number (Tan) of Bio-Oils," *Am. J. Biomass Bioenergy*, vol. 4, no. 1, pp. 1–9, 2015, doi: 10.7726/ajbb.2015.1001.

[18] E. Marlina, W. Wijayanti, L. Yuliati, and I. N. G. Wardana, "The role of pole and molecular geometry of fatty acids in vegetable oils droplet on ignition and boiling characteristics," *Renew. Energy*, vol. 145, pp. 596–603, 2020, doi: 10.1016/j.renene.2019.06.064.

[19] B. Waluyo, M. Setiyo, Saifudin, and I. N. G. Wardana, "The role of ethanol as a cosolvent for isooctane-methanol blend," *Fuel*, vol. 262, no. October, p. 116465, 2020, doi: 10.1016/j.fuel.2019.116465.

[20] M. T. Pham, A. T. Hoang, A. T. Le, A. R. M. Said Al-Tawaha, V. H. Dong, and V. V. Le, "Measurement and prediction of the density and viscosity of biodiesel blends," *Int. J. Technol.*, vol. 9, no. 5, pp. 1015–1026, 2018, doi: 10.14716/ijtech.v9i5.1950.