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To Study the Effect of Compression Ratio and Additives on Performance and Emission Characteristics of Hybrid Methyl Ester (Undi + Waste Cooking Oil) on Diesel Engine

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ABSTRACT: This project deals with synthesizing good quality of Methyl Ester from Mexicana seeds which is available cheaply in rural areas and grown in marginal lands. Different blends of Undi and waste cooking/fired oil are prepared in order to investigate the properties of blends and if necessary eco-friendly additives are added with blends. Also, it deals with validation of properties of synthesized Undi and waste cooking/fired oil Methyl ester according to ASTM 6751-96 standards. Biodiesel from edible waste cooking oil (waste cooking oil methyl ester – WCOME) has been produced via trans-esterification process. The effect of various fuel blends containing the conventional diesel fuel and the produced WCOME on diesel engine performance has been evaluated experimentally. The study investigated the effect of WCOME blending ratio on viscosity and sooting propensity of the biodiesel–diesel fuel mixture. Consumption of fossil fuels to meet increasing demand of globalization is increased considerably resulting in depletion of fossil fuel reserves. Stringent environmental norms and increase in greenhouse gases emissions has forced researchers to search alternatives to fossil fuels. Biodiesel (Methyl Ester) is one of the alternatives that can be used as fuel in conventional diesel engine without any design modifications.

KEYWORDS: Methyl Ester, Waste Cooking oil, Undi , CI Engine.

I. INTRODUCTION

The inventor of the diesel engine, Rudolf diesel, in 1885, used vegetable oil (peanut oil) as a diesel fuel for demonstration at the 1900 world exhibition in Paris. Biodiesel refers to a vegetable oil or animal fat-based diesel fuel consisting of long-chain alkyl (methyl, ethyl or propyl) esters. Biodiesel is typically made by chemically reacting lipids e.g., vegetable oil, soybean oil, animal fat with an alcohol producing fatty acid esters. Globally, the awareness of energy issues and environmental problems associated with burning fossil fuels has encouraged many researchers to investigate the possibility of using alternative sources of energy instead of oil and its derivatives. Among them, biodiesel seems very interesting for several reasons: it is highly biodegradable and has minimal toxicity, it can replace diesel fuel in many different applications such as in boilers and internal combustion engines without major modifications. Biodiesel has been in use in many countries such as United States of America, Malaysia, Indonesia, Brazil, Germany, France, Italy and other European countries. Research works on such studies show that different kinds of vegetable oils such as cottonseed oil, soybean oil, sunflower oil and their corresponding methyl esters, rapeseed oil methyl ester, palm oil methyl ester, corn oil, olive kernel oil, deccan hemp oil, jojoba oil, paradise oil, eucalyptus oil, poon oil, pongamia pinnata methyl ester, coconut oil based hybrid fuels and pre heated waste frying oil has been used as an alternative fuel for diesel engine. In these entire cases, engine showed an improved performance with reduction in smoke, hydrocarbon and CO emissions and increase in NOx emission. In this way, a lucid image has been formed

viewing the relative performance and emission characteristics of these fuels. However, the potential for its production and application is much more. Biodiesel has a massive potentiality to be a part of a sustainable energy mix in the future. Ethanol is an agricultural product and its use in diesel engine can help to boost the rural economy. Increased fraction of ethanol in diesel-ethanol blend has more potential to reduce the particulate matter as a result of increased oxygen content in the blend. The cold flow properties could also improve with the addition of ethanol. However, there are many technical barriers to the direct use of ethanol in diesel fuel due to the properties of ethanol, including low cetane number, poor solubility in diesel fuel in cold weather and lower flash point. In fact, diesel engines cannot operate normally on diesel-ethanol blend without special additives. Therefore, numbers of additives are developed to ensure solubility of diesel-ethanol blends. The low flashpoint of ethanol-diesel blend is also a technical barrier to the application of this fuel blend. Biodiesel derived from different sources is reported to act as an emulsifier for ethanol. Adding biodiesel in diesel-ethanol blend dramatically improves the solubility of ethanol in diesel fuel over a wide range of temperature. The diesel-ethanol-biodiesel fuel blends are stable well below zero temperature and have equal or superior fuel properties to regular diesel fuel.

II. LITERATURE SURVEY

[1] In the paper of 'Ali M.A. Attia, Ahmad E. Hassaneen' titled as 'Influence of diesel fuel blended with biodiesel produced from waste cooking oil on diesel engine performance.' The present work is aiming to produce biodiesel from waste cooking oil at high economic efficiency. Then the received biodiesel has been blended with neat diesel fuel at different blending ratios. Biodiesel from waste cooking oil can be produced economically with suitable properties for diesel engine application when catalyst of hydroxide potassium is used rather than hydroxide sodium [2] 'K. Muralidharan, D. Vasudevan' in with title 'Performance, emission and combustion characteristics of a variable compression ratio engine using methyl esters of waste cooking oil and diesel blends: The performance, emission and combustion characteristics of a multi fuel variable compression ratio engine fueled with waste cooking oil bio diesel and diesel blends have been investigated and compared with that of standard diesel. The experimental results confirm that the BTE, SFC, BP, exhaust gas temperature and mechanical efficiency of variable compression ratio engine, are a function of bio diesel blend, load and compression ratio. [3] In the paper of 'K.A. Abed, A.K. El Morsi, M.M. Sayed, A.A. El Shaib, M.S. Gad' with the title of 'Effect of waste cooking-oil biodiesel on performance and exhaust emissions of a diesel engine' talk Thermal efficiencies of waste cooking-oil biodiesel blends with diesel fuel were lower compared to diesel fuel and specific fuel consumptions were found to be higher. [4] 'K. Nanthagopala, B. Ashoka, B. Saravananb, M. Ramesh Pathyc, G. Sahila, A. Ramesha, Md Nurun Nabid, Mohammed Golam Rasuld With name of paper 'Study on decanol and Calophyllum Inophyllum biodiesel as ternary blends in CI engine' talk about. The experimental results are compared with diesel and diesel-biodiesel blend. The physical and chemical properties of decanol revealed that it could be used as a blending agent in CIME to overcome some of the drawbacks associated with pure biodiesels. The BSFC and BSEC of all the ternary blends are higher than diesel fuel but lower than biodiesel due to the sufficient amount of oxygen offered by alcohol. On the other hand, the BTE of all ternary blends are higher pure biodiesel and it increases with an increase in decanol concentration in the blend. [5] 'S. Nandha Gopan, A. Vennimalai Rajan, B. Radha Krishnan,' said in their paper with the title 'Review of Bio-diesel production from waste cooking oil and analyze the IC engine performance' said that The biodiesel production can be limited to 100 million gallons per year or less with the use of yellow grease, which can be achieved by using biodiesel from yellow grease. Comparing the biodiesel manufactured from soya bean oil, waste cooking oil will be cost-effective with the production of petroleum diesel. To meet the expectations of petroleum diesel cost, the cooking oil prices should undergo cost reduction to produce large quantities. EPACT, which is doesn't seem to increase in the upcoming years. The additive used in biodiesel contents will help as a cetane booster by the ultra-low sulfur diesel program. The biodiesel products can control unwanted emissions like carbon monoxide, sulfur contents, and also eco-friendly in our environment [6] 'A. Sanjid n, H.H. Masjuki, M.A. Kalam, S.M. Ashrafur Rahman, M.J. Abedin, S.M. Palash' said in the paper of title 'Impact of palm, mustard, waste cooking oil and Calophyllum inophyllum biofuels on performance and emission of CI engine' that Biofuel is taking its position every day over OD fuel because of the increasing trend of petroleum price and the environmental advantages. Moreover, industrialization and luxurious lifestyle have increased energy consumption more than ever before, which left no options without depending on renewable alternative fuel sources in near future. Though the use of biofuel is not a new invention but industrial production and establishment of biofuel as a successful alternative to diesel fuel is still a modern, challenging and prospective area for researchers. This paper critically reviews experimental results on fuel properties, performance and emission of four prospective biofuels derived from both edible and non-edible feedstock. However, tremendous demand of edible oil all over the world

criticizes edible oils as an ideal feedstock. Thus attention is shifted to non-edible vegetable oils sources like *C. inophyllum*, WCO or inedible low quality MSO. Following findings are summarized from the review of four specific biofuels: [7] S.K. Nayak, A.T. Hoang, B. Nayak, P.C. Mishra in their paper he present study briefly elaborates the overall performance, combustion and emission characteristics of a single cylinder direct injection diesel engine fuelled with waste palm cooking oil biodiesel and fish oil biodiesel individually and in post mixed methyl ester in contrast to that of conventional diesel fuel. [8] 'Ambar Gaur, Shubham Mishra, Subhankar Chowdhury, Prashant Baredar, Puneet Verma' said that WCO certainly reduces feedstock cost but needs pretreatment since it has high FFA value. The selection of catalysts and process intensification techniques become important while producing biodiesel licantly available waste cooking oil as potentially low cost feedstock for biodiesel production. It will also help India to achieve its sustainable development goals. Various studies have been reviewed under this study which can be concluded based on those. [9] In the title of paper 'The effects of the fuel injection pressure on the performance and emission characteristics of a diesel engine fuelled with waste cooking oil biodiesel-diesel blends' by 'Murat Kadir Yesilyurt' said that In this study, the biodiesel was produced from WCO which was collected from a local restaurant. The obtained biodiesel was blended with the standard diesel fuel in various ratios (B5, B10, B20, and B30). After that, the physical and chemical properties of the fuel samples were measured and compared with the standards. Finally, the fuel samples were performed in a single cylinder diesel engine in order to investigate the influence the fuel injection pressure (170e220 bars) on the performance and exhaust emission characteristics. The following findings were obtained the result of the present study. [10] Hwai Chyuan Ong, Jassinnee Milano, Arridina Susan Silitonga, Masjuki Haji Hassan, Abd Halim Shamsuddin, Chin-Tsan Wang, Teuku Meurah Indra Mahlia, Joko Siswanto, Fitranto Kusumo, Joko Sutrisno in their research work title as 'Biodiesel production from *Calophyllum inophyllum*-*Ceiba pentandra* oil mixture: Optimization and characterization' reported that In this study, a novel modeling approach (Artificial neural network (ANN) coupled with Ant colony algorithm (ACO)) was used to optimize the process variables (methanol-to-oil molar ratio, KOH catalyst concentration, and reaction time) of alkaline-catalyzed transesterification in order to maximize the *Calophyllum inophyllum*-*Ceiba pentandra* methyl ester (CICPME) yield. The physicochemical properties of the four crude *Calophyllum inophyllum*-*Ceiba pentandra* oil mixture (CICPO) mixtures (CI20CP80, CI40CP60, CI60CP40, and CI80CP20) were measured and the CI40CP60 oil mixture was chosen for in situ acid-catalyzed esterification and alkaline-catalyzed transesterification as well as optimization of the transesterification process variables because the oil mixture offered the best trade-off in terms of the kinematic viscosity at 40 °C, density at 15 °C, acid value, and higher heating value. Next, the ANN-ACO model was used to optimize the transesterification process variables in order to maximize the CICPME yield. Sensitivity analysis was also performed to determine the relative importance of each process variable on the CICPME yield. [11] 'G. Uguza, A.E. Atabanib, M.N. Mohammedc, Sutha Shobanad, S. Uguze, Gopalakrishnan Kumarf, Ala'a H. Al-Muhtaseb in their paper talk about The usage of biodiesel remarkably contributes to reduce the world's dependence on fossil fuels besides its well-known positive environmental impact. As biodiesel can be obtained from different sources, physico-chemical properties and chemical composition depend on the fatty acid composition and the quality of the feedstock. Waste cooking oil has been proved to be one of the best options for biodiesel production as it can be easily collected besides it does not create any land issue and food versus energy conflict.' [12] 'Arivalagan Pugazhendia, Avinash Alagumalaib, Thangavel Mathimanic, A.E. Atabanid' studied In India, the use of waste cooking oil for biodiesel production will help to bring significant environmental benefits because it offers an alternative to the disposal of the waste cooking oil into the environment. Furthermore, the use of waste cooking oil would minimize the cost of biodiesel production and pave way for sustainable biodiesel industry development in the country. In this investigation, the effects of experimental factors on waste cooking oil biodiesel yield were investigated by RSM-BBD approach (4 factors, three level designs). The second order polynomial regression model ($R^2 = 96.52\%$) was validated to be appropriate in the design of a similar reaction system. Furthermore, RSM integrated with desirability function approach was employed to find out the global solution for the best response. The results showed that the maximum biodiesel yield of $90 \pm 0.25\%$ with the optimum conditions. The optimum conditions identified are 0.6% w/w catalyst concentration, 10.6:1 methanol to waste cooking ratio, 559 rpm mixing intensity and 63 °C reaction temperature. The kinetic model of the process at different times and temperatures revealed that the reaction followed first order kinetics. The activation energy and frequency factor of the reaction were determined as 57.82 kJ/mol and 74×10^6 (min⁻¹), respectively. Moreover, the study of important thermodynamic parameters divulged that the reaction was endothermic, unspontaneous and endergonic in nature. In addition, this work suggests that future research should focus on the synthesis of "renewable diesel" from waste cooking oil by deoxygenation process' [13] In the title 'Performance, combustion and emission characteristics of diesel engine fuelled with waste cooking oil bio-diesel/diesel blends with additives' of 'S. Senthur Prabu, M.A. Asokan, Rahul Roy, Steff Francis, M.K. Sreelekh' reported that The study revealed that the WCOME and diesel blends could be successfully used as a source of alternate fuel in the diesel engine. The biodiesel blends (B0, B20, B30,

B40, B100, B30 þ BHT and B30 þ Butanol) were tested in a single cylinder four stroke direct injection diesel engine. The BSFC of B30 BHT is 7.3% higher than diesel and BTE 4.6% lower than diesel. The peaks in heat release of B20, B40 and B30 þ BHT are synchronous to diesel; B30 þ Butanol have higher heat release than diesel at higher loads. The values of cylinder pressure for different blends almost coincides with diesel fuel, whereas for B30 has 4.5% lesser than diesel fuel. B30þnbutanol have 37.5% less CO emission than diesel fuel and NO_x emission 9% more than diesel and EGT 2.3% higher than diesel fuel. On the other hand, EGT of B100 is 51% lesser than diesel fuel. Overall conventional diesel fuel is being best and the blends steadily reducing the performance such as BSFC and BTE as the fraction of biodiesel increases. At the same time, the performances of the mixtures are still very satisfactory for the B30 mixture with the fuel stability additive included, the bio diesel and its blends have better emission characteristics than diesel so from an environmental point of view WCOME will be a more promising alternative fuel in the near future [14] Calophyllum inophyllum oil, a renewable low-cost non-edible feedstock exhibits huge potential in the biodiesel production. The present study provides a comprehensive overview of its utilization as a promising feedstock for biodiesel owing to its suitable physiochemical properties. The crude extract of C. inophyllum oil shows very high acid value and therefore, its utilization for human intake was strictly neglected. From the literature, it was observed that maximum of C. inophyllum based biodiesel production was carried out using a homogeneous catalyst, which reflects the necessity of attention over the employment of heterogeneous catalyst. Also, the application of ultrasound and microwave should also be encouraged to enhance the biodiesel yield or conversion. No reports are available concerning the commercial scale production, kinetic studies and application of advanced statistical optimization tools on biodiesel production using C. inophyllum oil. Hence, further research is necessary to explore the complete potential of C. inophyllum feedstock for biodiesel production. was discussed by 'S. Niju, M. Balajii, G. Vishnupriya, K. M. Meera Sheriffa Begum and N. Anantharaman' in the research topic as 'Prospects and Potential of Calophyllum Inophyllum as a Renewable Feedstock for Biodiesel Production.'

[15]'G.R.K Sastry' publish a research work in the area of methyl ester name as 'Investigations on the Performance of an IDI Diesel Engine Using Azadirachta Indica and Calophyllum Inophyllum Linn Bio Diesel Blends and Ethanol' had studied that The . Cylinder pressure increases with increase in injection pressure, in case of blended fuels. CO emissions and smoke thickness can be reduced knowingly, by mixed fuels with ethanol as the stabilizer. Additional they are originating to reduction with the upsurge in inoculation pressure. NO emissions were reduced slightly by using mixed fuels with ethanol as the stabilizer. However, they are found to increase with injection pressure.

III. CRITICAL DISCUSSION ON LITERATURE REVIEW

- Pro Production methodology of biodiesel undi + waste cooking oil was explained and optimization is done by various researchers. They concluded that further research and development on some advanced methods such as super critical methanol process in situ alkaline transesterification and micro wave method is necessary. (1)
- Many searchers used biodiesel production from waste cooking oil has economic benefits as its cost is the lowest almost among both alternative and convictional fuels. The present work aiming to produce biodiesel from cooking oil at high economic efficiency .(2)
- Performance emission and combustion characterization waste cooking oil an diesel blend and C.R. Performance emission and combustion characterization of multi fuel variable C.R engine fuelled with waste cooking oil biodiesel and diesel blends have been investigated and compared with standard diesel. B40 blends is superior when compared with th conventional standard diesel at C.R21. Effect of waste cooking oil, performance and exhaust emission of a diesel engine. Many research diesel engine run at single cylinder waste cooking oil biodiesel blends B10,B20,b30 different load 1,2,3,4kw at speed 1500rpm.blends with thermal efficiencies lowered compared to specific fuel consumption is higher .Higher exhaust gas temperture recorded for waste cooking oil biodiesel blend diesel fuel for entire load. CO, HC, other emission lower cooking oil and NO_x and CO₂ emission increased percentage of biodiesel increased.(2,3)
- Study on decanal and callophyllum biodiesel a ternary blend in CI engine .in the research study diesel-biodiesel blends 10%,50%,20%,30%and40% concentration by value during the investigation diesel engine is running smoothly without any major modification .production of longer chain diaconal is feasible in large scale aspect in the engine performance characteristics .(4)
- Biodiesel production waste cooking oil and analyse the IC engine performance the bio diesel production

can be limited 100 million gallons per year less with the use of yellow grease achieved by using bio diesel product can be control unwanted emission like carbon monoxide sulphur content and also eco friendly in our environment. In this research paper we can study various oil like palm oil, waste cooking oil and Calophyllum inophyllum oil their impact on CI engine. Palm oil has versatile quality in term of productivity oil yield and land utilization and WCO is most economic sources of biofuels which efficiently helps in liquid waste management and prevents recycling of used oil and Calophyllum is completely non edible and transesterification oil.(5,6,12)

- In this paper we can study various parameters like BSFC, highest load, NO_x emission is lower than diesel at full load. In that literature survey we can check engine performance of biodiesel, the biodiesel was produced from waste cooking oil was collected from local restaurant. In further study, the cost analysis will be performed for the production of biodiesel from WCO in order to compare with the standard diesel fuel. Moreover, thermodynamic, environmental and economic analyses are going to be applied to the diesel engine fuelled with WCOB and its blends with diesel fuel.(7,9)
- In this paper we can observe the waste cooking oils easily available in India and also it is the low cost so using process intensification techniques like ultrasound assisted microreactor showed a better result than conventional method the main conclusion part is the selection on the type of catalyst and process intensification technique significantly affects the transesterification process. We also find the relative importance of each process variable on the CICPME.(10,11)
- Calophyllum inophyllum oil, a renewable low-cost non-edible feedstock exhibits huge potential in the biodiesel production. NO_x emissions were reduced slightly by using mixed fuels with ethanol as the stabilizer. However, they are found to increase with injection pressure.(14,15)

IV. NOMENCLATURE

NO_x = OXIDES OF NITROGEN
 NaOH = SODIUM HYDROXIDE
 KOH = POTASSIUM HYDROXIDE
 CO = CARBON MONOXIDE
 BTE = BRAKE THERMAL EFFICIENCY
 CO_2 = CARBON DIOXIDE
 HC = HYDRO CARBON
 FP = FLASH POINT
 ASTM = AMERICAN SOCIETY FOR TESTING AND MATERIALS
 VCR = VARIABLE COMPRESSION RATIO
 B20F02 = 6 TO 20% BIODIESEL & 2% ADDITIVES

IV. CONCLUSION

1. Calophyllum Inophyllum oil, is a low cost non edible feedstock which has a huge potential in biodiesel production
2. Thermal efficiencies and specific fuel consumption of waste cooking oil were found to be lower and higher respectively compared to diesel
3. The study revealed that the Undi (Calophyllum inophyllum) and waste cooking oil can be used as an alternate solution for biodiesel fuel in diesel engine.
4. Waste cooking oil has been proved to be one of the best options for biodiesel production as it can be easily collected without any land issues and versus energy conflict compared to other biodiesel.

REFERENCES

- [1] Ali M.A. Attia, Ahmad E. Hassaneen, as Influence of diesel fuel blended with biodiesel produced from waste cooking oil on diesel engine performance, Fuel, 2015.
- [2] . Muralidharan, D. Vasudevan, Performance, emission and combustion characteristics of a variable compression ratio engine using methyl esters of waste cooking oil and diesel blends Applied Energy 88(2011) 3959-3968.

- [3] K.A. Abed , A.K. El Morsi , M.M. Sayed , A.A. El Shaib , M.S. Gad, The Effect of waste cooking-oil biodiesel on performance and exhaust emissions of a diesel engine, Egyptian Journal of Petroleum (2018).
- [4] K. Nanthagopala , B. Ashoka , B. Saravananb , M. Ramesh Pathyc , G. Sahila , A. Ramesha , Md Nurun Nabid , Mohammed Golam Rasul z, Study on decanol and Calophyllum Inophyllum biodiesel as ternary blends in CI engine, Fuel 239 (2019) 862-873.
- [5] S. Nandha Gopan , A.Vennimalai Rajan , B. Radha Krishnan , Review of Bio-diesel production from waste cooking oil and analyze the IC engine performance, 2020.
- [6] A. Sanjid n,H.H. Masjuki, M.A. Kalam,S.M. Ashrafur Rahman, M.J. Abedin, S.M. Palash, Performancempact of palm, mustard, waste cooking oil and Calophyllum inophyllum biofuels on performance and emission of CI engine, Renewable and sustainable Energy Reviews 27 (2013) 664-682.
- [7] S.K. Nayak , A.T. Hoang , B. Nayak , P.C. Mishra , Influence of fish oil and waste cooking oil as post mixed binary biodiesel blends on performance improvement and emission reduction in diesel engine, Fuel, 289 (2021) 119948.
- [8] Ambar Gaur , Shubham Mishra , Subhankar Chowdhury , Prashant Baredar , Puneet Verma , A review on factor affecting biodiesel production from waste cooking oil: materials, Proceedings 2020.
- [9] Murat Kadir Yesilyurt, The effects of the fuel injection pressure on the performance and emission characteristics of a diesel engine fuelled with waste cooking oil biodiesel-diesel blends, Renewable Energy 132(2019) 649 -666.
- [10] Hwai Chyuan Ong , Jassinnee Milano , Arridina Susan Silitonga , Masjuki Haji Hassan , Abd Halim Shamsuddin , Chin-Tsan Wang , Teuku Meurah Indra Mahlia , Joko Siswanto , Fitranto Kusumo, Joko Sutrisno Biodiesel production from Calophyllum inophyllum-Ceiba pentandra oil mixture: Optimization and characterization, Journal of Cleaner Prodction 219 (2019) 183-198.
- [11] G. Uğuza , A.E. Atabanib , M.N. Mohammedc , Sutha Shobanad , S. Uğuze , Gopalakrishnan Kumarf , Ala'a H. Al-Muhtasebg, Fuel stability of biodiesel from waste cooking oil: A comparative evaluation with various antioxidants using FT-IR and DSC techniques, Biocatalysis and Agricultural Biotechnology 21 (2019) 101283.
- [12] Arivalagan Pugazhendhia , Avinash Alagumalaib , Thangavel Mathimanic , A.E. Atabani, Emission Optimization, kinetic and thermodynamic studies on sustainable biodiesel production from waste cooking oil: An Indian perspective, Fule 273 (2020) 117725.
- [13] S. Senthur Prabu, M.A. Asokan , Rahul Roy, Steff Francis, M.K. Sreelekh, Performance, combustion and emission characteristics of diesel engine fuelled with waste cooking oil bio-diesel/diesel blends with additives, Energy 122 (2017) 638-648.
- [14] S. Niju, M. Balajii, G. Vishnupriya, K. M. Meera Sheriffa Begum and N. Anantharaman Prospects and Potential of Calophyllum Inophyllum as a Renewable Feedstock for Biodiesel Production, .
- [15] G.R.K Sastry, Experimental Investigations on the Performance of an IDI Diesel Engine Using Azadirachta Indica and Calophyllum Inophyllum Linn Bio Diesel Blends and Ethanol, Materials Science and Engineering 377 (2018) 012083.



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