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ENHANCEMENT OF FAME PRODUCTION FROM PUNGAI SEED OIL USING ARTIFICIAL NEURAL NETWORK

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Abstract The objective of this project to reduce the cost and emission of the diesel engine without affecting its efficiency, performance and without any modification of the engine. Pungai oil (Oil extracted from Milletia pinnata) is the most promising source for biodiesel. This oil is blended with the diesel with a specific composition. An appropriate catalyst is added with the oil to increase the FAME and remove the Glycerine and other residues. The composition of this oil and diesel and other properties was predicted using a special machine learning algorithm called Artificial Neural Network. This Artificial Neural Network algorithm was simulated using python TensorFlow. The specialty of this project is we used heterogeneous catalyst for the Transesterification process. This significantly reduces the cost and emissions without affecting its performance.

Keywords: Biodiesel, Chromium oxide Nanoparticles, Pungai Seed oil, Transesterification, Pollution control, Machine Learning, Artificial Neural Network, Nanocatalyst.

1 INTRODUCTION

The major problem in our society is the depletion of fossil fuels. Biofuel is created as a substitute for diesel. The reason for the need biofuel is that it can be used in today's engines, vehicles without the need to make any changes in the engine. Biofuel can be used, burned in the same way as petroleum diesel fuel. It can also be used in blended or pure forms in the IC engines safely. The fuel economy will benefit from using biofuel as it is nearly identical to diesel fuel and can be utilized like conventional diesel.

In India, transportation causes more than a fifth of the total greenhouse gas emissions and causes global warming. With the appropriate method of production, biofuel will produce very less amount of greenhouse gas emission than currently used fossil fuels. This leads us to the potential of finding the important challenges we face today regarding fuel quality and emission of diesel engines. Biodiesel is also said to be the most successful alternative fuel to complete the dangerous emissions and health study under EPA's Clean Air Act. Biofuel will reduce emissions of many toxic gases of which causes global warming. The energy balance of fuel is the ratio of how much energy is required to produce the fuel, manufacture and distribute to compare to the amount of energy that is utilized when fuel is used. As energy security continues to grow as a topic in both international societies and governments around the world, biofuel has a high energy balance compared to other fuel alternatives such as electric CNG. A steady supply of affordable energy is required for a country otherwise the economy of the country will come to a halt with no energy to run power plants, transportation, and heat homes.

Biofuel will help to improve energy security and it will help to improve energy balance through domestic energy crops and seeds. The plants are used to produce biofuel in replacement of imported expensive crude oil. Biofuel will also improve the overall national capacity to reduce the need for importing crude oil. Increasing the investment in biofuels will result in an increase in the economy and GDP in the country. This causes that there will be more jobs and new sources of income for farmers in the local industry. Developing countries will benefit a lot from the economic growth in the demand for world energy. The demand is expected to increase by 84% as new sources of energy such as biofuel will be expected to meet this requirement.

Biofuel is proven to be less toxic than diesel as its attributes make it less likely to harm the environment. Biofuel is less toxic than table salt as it is natural, non-toxic vegetable oil. Biofuel is also fifteen less toxic than common species of fish and also it can be produced from waste products.

Biofuel is safer to handle than petroleum fuel and diesel due to its low volatility. The higher amount of energy does make it a danger of accidental ignition as the fuel will create enough vapour to ignite. It can be done with different fats and oils, including waste cooking oil. Recycled oils will increase their value and more cost effective. With Biofuels, this helps to create multiple benefits to a thriving market. In India, green fuels are being used around the continent and are expected to grow by 2022.

2 MATERIALS

2.1 PUNGAI SEED (MILLETIA PINNATA)

Millettia pinnata is a tree that grows to about 15–25 meters in height with a large canopy that spreads equally wide. The Pungai seed of 38 kilograms was purchased from a local store in Nagercoil. We selected the expeller pressing method for the extraction of pungai seed oil due to its low cost and reliability.

Figure 1 Pungai seed oil

The process was carried with the help of a local oil mill operator at Thangam oil mil in asaripallam. First, the outer shell of the seed was removed by a pressing machine in the mill. Then seed was sent through the expeller pressing machine a thread-like pressing machine crushes and squeezes the seed. This causes the separation of oil from the seed. The temperature of the oil reached up to 48 degrees Celsius during the process. Then the remaining sediments were cleaned the pure oil was separated. Then the oil is stored at room temperature in bottles.

2.1.1 PROPERTIES OF PUNGAI SEED OIL

PROPERTIES	VALUE
Water Content	0.05%
Specific Gravity	0.9366
Density	0.9358 gm/cc
Carbon Residue	0.80%
Ash Content	0.05%
Flash Point	2120C
Fire Point	2240C
Acid Value	16.8
Boiling Point	330^{0}C
Sediments (insoluble in hexane)	0.006%
Cloud Point	2^{0}C
Pour Point	-4^{0}C
Calorific Value(Kcal/kg)	8742
Cetane Number	38
Saponification Value	85.7
Unsaponifiable matter	0.90%

Table 1 Properties of Pungai seed oil

Fatty Acid	Molecular formula	Percentage
Palmitic acid	C16H32O2	11.65
Stearic acid	C18H36O2	7.5
Oleic acid	C18H34O2	51.59
Linoleic acid	C18H32O2	16.64
Eicosanoic acid	C20H40O2	1.35
Dosocasnoic acid	C22H44O2	4.45
Tetracosanoic acid	C24H48O2	1.09
Residual		6.83

Table 2 Chemical Compounds

2.2 CHROMIUM OXIDE NANO CATALYST

In this project, we selected heterogeneous Nano catalyst for the production of biodiesel due to their eco-friendly properties. Unlike homogenous catalysts, they can be easily separated from the oil after the transesterification process. The oil and the catalyst are in different phases so some types of catalysts can be reused again for the transesterification process after some pre-treatments. This will significantly reduce the cost of biodiesel because the catalyst just increases the rate of chemical reaction, the catalyst will not be consumed after the reaction.

For this project, we purchased Chromium Oxide(Cr_2O_3) Nanoparticles from NRL Nano products, Jharkhand. Chromium oxide occurs naturally from the mineral, which is found in chromium-rich tremolite skarns, metaquartzites, and chlorite veins.

2.2.1 SYNTHESIS OF CHROMIUM OXIDE

500 ml of 0.1M solution of $Cr_2(SO_4)_3$ was taken and aqueous ammonia was added dropwise with constant stirring until the pH of the solution reached 10. The precipitates thus obtained were filtered by a Buckner funnel and were washed many times with distilled water carefully. The precipitates were dried at 70°C for a day and were calcined at 650°C in a muffled furnace for 5 hrs. The produced material was ground and sieved through a 100 mesh size sieve in at clean environment.

2.2.2 CHARACTERIZATION OF CHROMIUM OXIDE

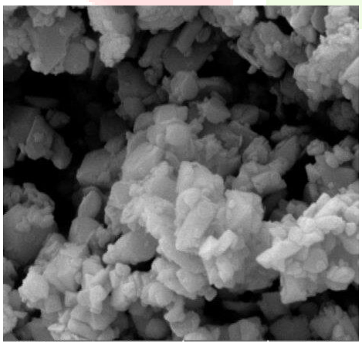

Figure 2 SEM image of Cr_2O_3

Catalyst surface morphology was studied using SEM analysis for which a JSM 6360LA instrument was used. Figure 2 shows the surface morphology of the Cr2o3.

The functional groups present on the surface of the catalyst were identified using an FTIR spectrometer using IR wave. It was analyzed using a PerkinElmer Spectrum 100 FTIR instrument having a universal diamond attenuated total reflectance sampling tool. For interpretation, infrared data were collected between the wavelength of 400 and 2000 cm−1. Phase identification of the catalyst was analysed using X'pert Pro model, PAN analytical diffractometer instrument working on Cu Kα radiation source which was carried out in the scanning 2θ ranging from 5° to 95° having 0.04° as step size. Debye-Scherer's relationship as shown in was used to calculate the crystalline size of the sample. $T = 0.94\ \lambda / \beta\cos\theta$. Where, T is the average particle size of Cr_2O_3, λ is the X-ray wavelength measured, β is the full width at half maximum and θ is the diffraction angle. Mastersizer 3000 laser scattering particle size analyser (Malvern instrument Ltd., Worcestershire, UK) was used to determine the particle size distribution of the prepared catalyst. The size of the particles ranging from 20 nm to 60 nm was measured.

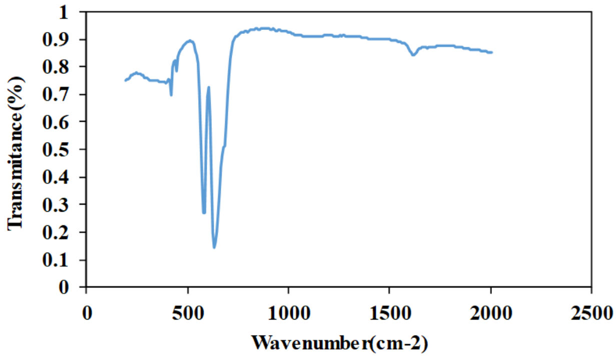

Figure 3 FTIR Spectrum of Nano Catalyst Cr_2O_3

X-ray diffraction of synthesized oxide is shown in Figure 4 The X-ray diffraction plot, shows peaks only due to Cr_2O_3 and no peak is detected due to any other material or phase indicating a high degree of purity of the as-synthesized sample we have used for the inspection. The broadening of the X-ray diffraction lines, as seen in Figure 4 reflects the Nano-particle nature of the sample. In the X-ray diffraction, some prominent peaks were considered and very less values were neglected, corresponding d-values were compared with the standard. X-ray diffraction shows that the formed Nano metal oxide is pure Cr_2O_3 and having a hexagonal structure.

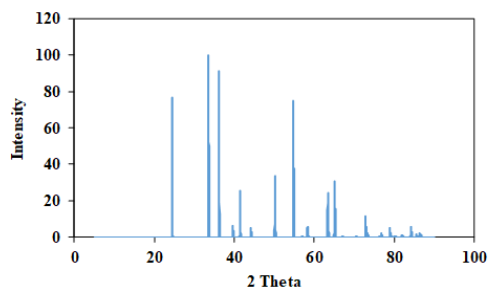

Figure 4 X-Ray Diffraction Spectrum of Cr2O3

3 METHODOLOGY

3.1 TRANSESTERIFICATION

The transesterification process was carried out in a two-neck 300 mL bottom glass flask fitted with a temperature controller and a magnetic stirrer. A reflux condenser set up was fixed to one of the top necks to reflux back the methanol evaporated during the reaction from the sample. The oil was warmed to 60 °C before the experiment. Initially, a known quantity of oil was charged into the reactor and the oil was then preheated at different process temperatures (40–80 °C) to which the catalyst mixed with methanol was added. Different concentrations of the catalyst (1–8 wt.%), methanol to oil molar ratio (6:1–24:1), and reaction time of 30–330 min were taken for optimization. The reaction was performed at a constant stirring rate of 500 rpm. The one factor at a time method was followed for optimization in which only one parameter was varied at a time while keeping the other variables constant.

The concentrations of the selected parameter were then changed over the desired range for better optimization. The stirring was stopped at the end of every reaction time and the resultant mixture was set aside to cool for a certain amount of time. Meanwhile, the catalyst was separated using a filter. The samples were kept for a day to separate the final mixture to form two layers where the top layer was biodiesel and the bottom glycerol. The upper biodiesel layer was separated and dried and used to determine the yield of biodiesel gravimetrically.

$$\text{Biodiesel yield (wt.\%)} = \frac{Weight\ of\ biodiesel\ (g)}{Weight\ of\ oil\ (g)}$$

3.2 BLENDING OF BIODIESEL

After the completion of transesterification, the produced biodiesel was blended with pure diesel with specific composition to get maximum performance. We blended the biodiesel with 4 different combinations. The biodiesel blends were stored in four different containers.

S.No	Label	Diesel	Biodiesel
1	B20	80%	20%
2	B15	85%	15%
3	B10	90%	10%
4	B5	95%	5%

Table 3 Biodiesel blends

A four-cylinder 2.1 litre Diesel engine was used to test the biodiesel. Before starting the testing all precautions were made. All the mechanical testing was done simultaneously all the emission tests were carried out. The test was also done for pure diesel in order to compare the performance with pure diesel. Due to the absence of sulphur and many substances in the Pungai oil the emission is significantly reduced as compared with the pure diesel.

3.3 ARCHITECTURE OF ARTIFICIAL NEURAL NETWORK

For this project, an artificial neural network was developed in Python 3.7.8 for predicting the appropriate blending ratio of the biodiesel and the maximum possible yield of biodiesel. The number of output neurons was selected depending on the number of varying parameters such as emission, brake thermal efficiency, brake specific fuel consumption, brake power, totally of 8 input neurons were selected for our neural architecture. A single output neuron is used. The number of hidden layers were 2 and each layer consist of 5 neurons. The number of neurons and iterations should be optimum to avoid under fitting of overfitting. For another neural network the number of input neurons was four and a single output neuron is used the hidden neurons are same for both model.

3.3.1 IMPLEMENTATION OF NEURAL NETWORK

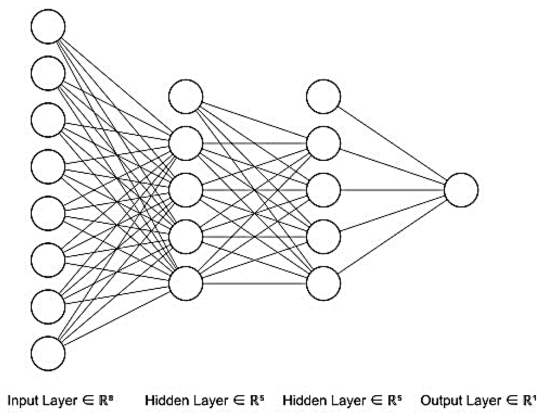

Figure 5 Architecture of Neural Network

Python 3.7.8 is installed and TensorFlow 2.4.1 library was used to make the neural network. At first, the data was loaded into the python program after that all the data were converted into a matrix using the numpy library. In the next step the input layer, output layer, and all the hidden layers were activated by ReLu function. The output function was not activated by sigmoid or softmax functions because we were using this network regression. After the creation of neural network, the data was fed into the neural network. The number of epochs was selected is 1200.

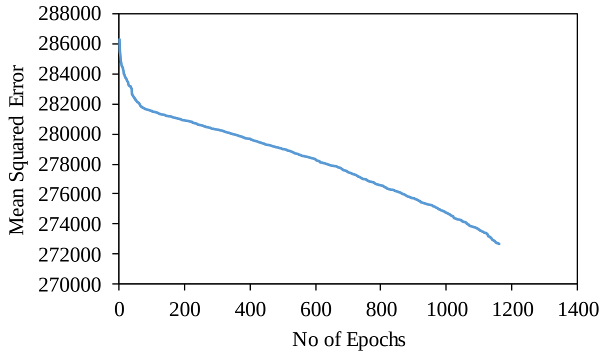

Figure 6 Epochs vs Error for Model 1

The model has predicted that the higher temperature and reaction time gives higher yield, the model has approximately predicted the yield of biodiesel which is good enough to make decisions.

Duration	Catalyst	Temperature	Molar ratio	Yield	Predicted Yield
60	1.2	50	6:1	42.16	44.06
70	1.5	50	7:1	51.7	48.62
80	1.8	50	8:1	52.23	53.19
90	2.1	50	9:1	52.79	54.75
60	1.2	60	6:1	43.59	44.7
70	1.5	60	7:1	52.43	52.46
80	1.8	60	8:1	53.7	57.02
90	2.1	60	9:1	58.36	61.58
60	1.2	70	6:1	48.79	51.13
70	1.5	70	7:1	55.76	56.04
80	1.8	70	8:1	71.19	71.86
90	2.1	70	9:1	70.12	69.42
60	1.2	80	6:1	51.62	53.57
70	1.5	80	7:1	57.31	59.48
80	1.8	80	8:1	57.83	58.39
90	2.1	80	9:1	70.18	69.26

Table 4 Predicted Yield

Then the model was performed over 32,000 times to check the multiple possibilities. The maximum possible Yield predicted was at 72-degree C, duration of 88 minutes, catalyst weight 1.9 grams, the molar ratio is 7.5 the yield predicted was 74.56%.

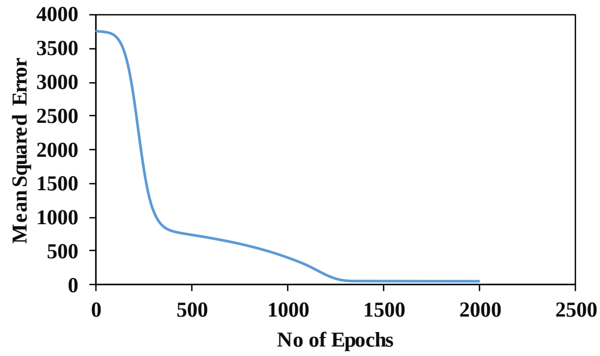

Figure 7 Epochs Vs Error for Model 2

Then a second model was created to simulate the maximum performance of the biodiesel. For this network, 5 hidden layers of each layer containing 7 neurons selected after that the model was iterated 2000 times to get accurate results.

Blend	HC	CO	NOx	Smoke	BSFC	BTE
B2	25.762	3.704	20.402	2.068	7.962	13.108
B3	25.238	3.631	19.986	2.028	7.8	12.84
B4	24.704	3.556	19.56	1.986	7.634	12.568
B5	24.168	3.481	19.134	1.943	7.468	12.298
B6	23.634	3.405	18.708	1.901	7.304	12.026
B7	23.098	3.33	18.282	1.859	7.138	11.754
B8	22.564	3.255	17.856	1.816	6.972	11.482
B9	22.03	3.18	17.43	1.774	6.808	11.21
B10	21.494	3.104	17.004	1.732	6.642	10.938
B11	20.96	3.029	16.578	1.689	6.476	10.666
B12	20.424	2.954	16.15	1.647	6.312	10.394
B13	**19.89**	**2.878**	**15.724**	**1.605**	**6.146**	**10.122**
B14	19.356	2.803	15.298	1.562	5.98	9.85
B15	18.82	2.728	14.872	1.52	5.816	9.578
B16	18.286	2.653	14.446	1.478	5.65	9.306
B17	17.752	2.577	14.02	1.435	5.484	9.034
B18	17.494	2.541	13.816	1.415	5.406	8.904
B19	17.478	2.539	13.802	1.414	5.4	8.896
B20	17.3	2.514	13.66	1.4	5.346	8.806

Table 5 Predicted blends

After running the neural network for multiple times the model has predicted the performance based on the test conducted on the 4 data. For simplicity of the model the data was compressed to a simpler form. The predicted performance was shown in Table 5. For optimum performance and low emission, the B13 blending ratio was selected for the biodiesel. Then the B13 ratio was used and tested the performance and emission test again to compare with the predicted value.

Blend	HC	CO	NOx	Smoke	BSFC	BTE
B13	18.87	2.78	14.72	1.5	5.16	9.78

Table 6 Obtained performance in engine

The model has approximately predicted the performance parameters of the engine which is accurate enough to select the bending ratio of the biodiesel.

4 RESULT AND DISCUSSION

The graphs are plotted against various parameters. Brake power is considered at X axis and varying parameters are plotted against Y axis.

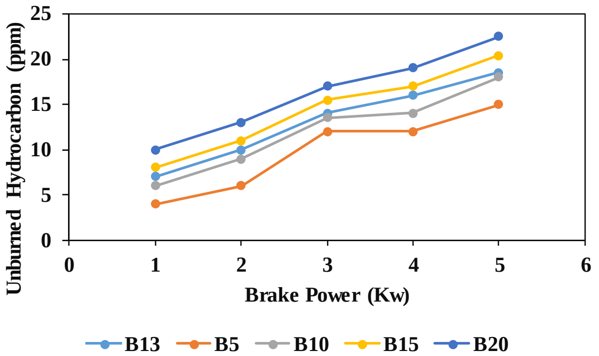

Figure 8 Unburned Hydrocarbon

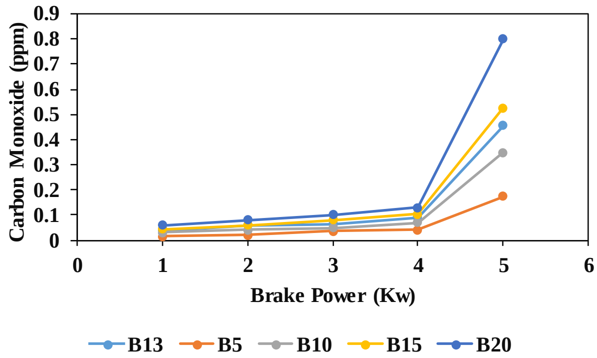

Figure 9 Carbon Monoxide

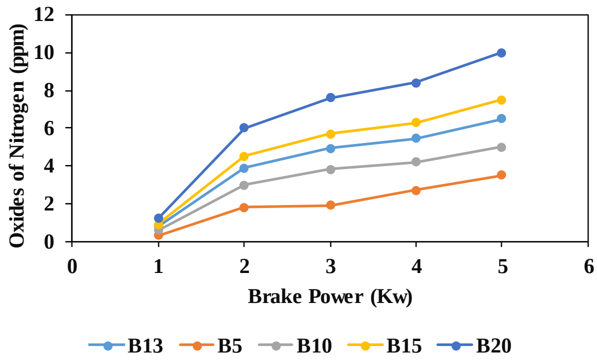

Figure 10 Oxides of Nitrogen

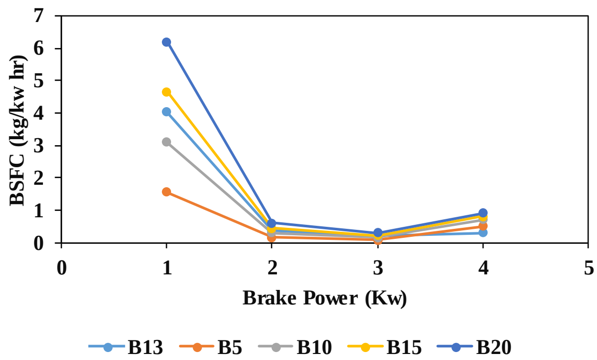

Figure 11 Brake Specific fuel consumption

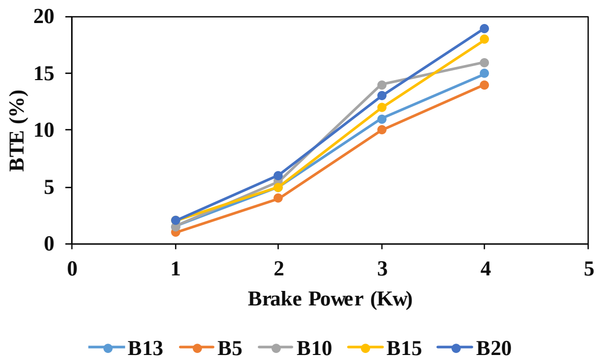

Figure 12 Brake Thermal Efficiency

The above figures clearly show that the B13 fuel is a good blending ratio as compared with others. B13 has an acceptable amount performance and emission compared with others and pure diesel.

5 CONCLUSION

It is finally concluded that the artificial neural network we used to predict the maximum yield percentage and blending ratio works. It is possible to optimize the biodiesel performance using artificial neural network. The pungai seed oil feedstock reduced a significant amount of emission as compared with pure form of diesel without affecting its performance the oil can be used in common diesel engine without any modifications. The heterogeneous catalyst (Cr_2O_3) gives reasonable yield and it is environmentally friendly.

It is advised to perform the transesterification process at 72-degree C, duration of 88 minutes, catalyst weight 1.9 grams, the molar ratio is 7.5 to get maximum amount of yield. And the blending ratio B13 significantly reduces the emissions and gives reasonable performance.

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