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Quantitative Improvement of Producing Biodiesel from Multiple Waste Cooking Oils with Simple Heterogeneous Catalyst

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Abstract

Transesterification of oils employing homogeneous catalysts is how the traditional process of producing bio-diesel from waste cooking oil (WCO) progresses. Unfortunately, there are some issues with the homogeneous catalytic reaction that make it challenging to isolate and cleanse the biofuel. Hence, we propose an effective experiment on making biodiesel using CaO (catalyst) from various WCOs. The objective of this investigation is to determine whether it is feasible to use CaO to create biodiesel from multiple kinds of WCO. The design of the test and parameter estimation was done using MATLAB software. The selected predictor factors' optimal values were discovered. The M-O molar ratio of 10.57:1.0, CaO of 6.73wt%, and response time of 101.03 minutes were the ideal conditions for the transesterification. Waste corn oil (WFCO) from frying was the ideal kind of oil. The test results for biodiesel production are a little less than 96%, while the optimal anticipated production was 95.64%. The quality attributes of the produced biodiesel and its blends B6-B20 were in acceptable accordance with the demands of global standards. It could thus be compatible and appropriate for diesel fuel.

Keywords: Bio-diesel, waste cooking oil (WCO), CaO catalyst, MATLAB

Full length article **CorrespondingAuthor*,e-mail:dkrachiata@jnujaipur.ac.in

1. Introduction

Methyl esters processes are frequently utilized to make biodiesel. The use of heterogeneous catalysts provides a number of benefits from over homogeneously catalytic biofuels synthesis technique, including the presence of toxicity, exclusion of neutralization, ease of reuse, and capacity to endure severe temperatures. Moreover, heterogeneous photocatalysis decreases operating expenses while simplifying the manufacturing of biodiesel, albeit at the expense of longer responses and larger catalyst maximums due to poor catalytic efficiency. As a consequence, the creation of affordable heterogeneous catalysts with high activity is sought for the long-term producing biodiesel [1]. WCO is being considered as a possible replacement for consuming oils in the manufacture of biofuels using various household related culinary activities or else from eateries. It is because WCO can reduce the price of basic supplies but, in addition, it also can effectively handle the basic problems related to the disposal of WCO [2]. Vegetable oils rose to prominence as alternative fuels for diesel engines in the 1930s and 1940s and were sometimes utilized as petrol liquid fuels, generally in dire situations. Because of their greater volume and instability, prepared vegetable oils used in automobiles for an extended period of time may cause substantial engine deposits, piston ring sticking, and injector constriction [3]. WCO is mostly generated in densely populated urban areas, particularly in houses, leisure areas, and food manufacturing businesses. As oil products being used in preparing food to degrade through oxidation, polymerization, and heat reactions that take place while boiling and fried, they could be utilized frequently [4]. About 70–80% of the entire cost of producing biodiesel is often attributed to the price of raw materials. Hence, highly efficient catalysts are required to produce biodiesel from non-edible and waste oil. In light of this, the goal of the current research was to lower the price of producing biodiesel from used cooking oil by employing cheap catalysts made of CaO [5].

A basic heterogeneous catalyst was created by synthesizing a hybrid model with pure diatomite supplemented by CaO/MgO composites. As a consequence of response time, catalysis dose, turning rate, catalyst/methanol ratios, and the prior catalysis' ability to be recycled for several adaptive processes, the biosynthetic catalysis was first utilized in the manufacture of WCO from biofuels [6]. In addition to preventing the same oil supplies from being used for both meals and transportation, the manufacturing of biodiesel from WCO will also address the issues in WCO storage. The price of the catalysts also makes

a significant sufficient contribution to the overall price of blended fuels. The production of reduced catalysts from waste products was one of the study topics related to the creation of a sustainable biofuel manufacturing process [7]. Also, the physico-chemical properties of the generated biodiesel and its mixtures with petro-diesel are being investigated in this research..

The research [8] centralized on the distinguishing features of seven different types of solid-state catalysts, including zeolite-based catalyst, layered-double-hydroxide-based catalyst, graphene oxide, activated carbon, biomass, and non-biomass wastes produced. Metal and steel catalyst bracings that are frequently used in established biofuel experiments have also been considered. To produce high-quality biodiesel and environmentally friendly diesel oil, 3 distinct methods were suggested [9] mixing eco-friendly petrol engine with groundwater pure diesel, creating composers of the enhanced fuel "eco-friendly petrol engine" with spore, and getting multiple blends of clean gasoline with micro. Through these techniques, gasoline for diesel may be produced with better lubrication characteristics; the worn surface width can be decreased to 232 mm, compared to the EN 590: 2009 minimum standards of up to 460 microns. Multiple ecologically friendly diesel fuels with increased flow ability were found to have the ideal qualitative content. The relationship between the quantitative and qualitative composition and the alteration in the lubrication qualities of eco-friendly petroleum diesel is discovered. In order to develop biofuels as an alternative to petroleum-based biofuels, the study [10] investigates the catalytic hydroxylation of WCO whilst considering economic and ecological instability factors into mind. In order to determine the optimal hydrolysis settings, clusters type experiments was employed. This biodiesel output underwent analysis, and its gasoline properties were identified against specifications.

The purpose of the research [11] was to sustainably assess the method currently used in Bogota, Colombian, for recovering and using WCO. In order to make biodiesel, UCO is now gathered, processed, and shipped often to Europe. Based on literature-based information and an analysis of the production process, several ecological standards have been developed, evaluated, and examined within the integrative concept of sustainability. Findings were contrasted to those from evaluating the existing supply of first-generation palm kernel oil biodiesel as a measurement device. The research [12] of the current various regulations for WCO collection and recycling policies adopted by important make containers compounds is complemented with an overview of the development of biofuels production processes and inventive ways to improve optimization's efficacy. The characteristics of the substrate, heterogeneous catalytic procedures, economic viability, and output specificity are only a few of the variables that are considered as affecting responses were recorded. In the research [13], WCO from eateries that serve fast food was utilized as the substrate, while glass powder and bone fragments were employed as the silica and calcium oxide supplies for the catalysis in a gasification process to produce biofuels. As long as ecological and moral biodiesel requirements are met, using waste or inedible oils to make biodiesel may stifle prices from supplies. Moreover, using waste fuels that are easily accessible and catalysis created from discarded materials is a more affordable and efficient method than using standard, pricey substrate and catalysis. The study [14] suggests that reuse may provide peasant communities with a source of sustained alternative revenue. A SWOC (strength, weakness, opportunity, and challenges) analysis is given to better understand the policies of various areas related to the collection of WCO, and a more suitable conversion strategy is announced after the examination of many acquiring techniques. The research [15] examines the manufacture of biodiesel from WCO by catalysis gasification as an alternative to petroleum and coal while taking ecological safety and economic hardships into consideration. To create CaO nanotubes (NPs),, and pure mustard ethanolic extracts were used to calcine chicken shavings at 900 °C. These particles then were saturated with only hydrogel solutions..

2. Materials and methods

Acquired gasoline (AR Grade) and pure calcium oxide as heterogeneous basic catalysts from India. The nearby facility provided industrial Egyptian hydrocarbon.

2.1. WCO gathering and preparation

In this analysis, various kinds of WCO are being used. Waste frying oils (WFO) were gathered from neighborhood eateries, whilst residential waste products were utilized to gather waste frying sunflower oil (WFSFO) and waste frying corn oil (WFCO). The gathered WCO was centrifuged and treated to remove any suspended materials, burnt food particles, etc. To eliminate any undesired water that was included through evaporation, it was then heated at 105oC for 2 hours.

2.2. Method of biodiesel production

The substance was permitted to segregate for an extended period after the response time specified. A separator was applied to separate the clean glycerol and solid catalyst from the bottom layer so that they could both be utilized anew. The dissolved formaldehyde that was present in the top layer of biofuels was washed off and put into a sampling vial that was put into desiccators and weighed that were designed to recover alcohol at 65°C and 20 kPa. Therefore, order to blend it with the conventional Egyptian oil refining and conduct evaluation experiments, the resulting purified bio-diesel was then packaged and stored. An output calculation was made for the biofuel. Using the formula is as follows:

$$\%\text{Yield} = \frac{\text{Weight of produced bio-diesel}}{\text{Weignt of used WCO}} \times 100 \quad (1)$$

2.3. Descriptive statistics and empirical planning

The studies developed enhance CaO hydrolyzed reaction via a series of meticulously supervised empirical analyses. Also, a prediction model that will specify the allocation of predictor variables (biodiesel yield) regarding four parameter estimates (factors). The following variables are taken into consideration: X_1 methyl to oil M:O methanol: water, X_2 CaO concentrations in weight percent,

X_3 reactions duration in minutes, and X_4 the kind of used frying oil. Using DOE at 3 separate stages, those factors are clarified and examined. Table 1 includes the configuration of the elements and the corresponding matched measurements made in addition to the research design with actual and planned reactions.

The 2nd statistical measure, symbolized by the following formula, was determined to be the greatest fit for estimating the output.

$$x = \beta_0 + \sum_{i=1}^{m} \beta_i y_i + \sum_{i=1}^{m-1 j=i+1} \sum_{j=i+1}^{n} \beta_{ij} y_i y_j + \sum_{i=1}^{m} \beta_{ij} y_i^2 \quad (2)$$

With x is the reactions yield (its % of biofuels produced), m is the number of components, βo is the potential target, whileβ_i,β_ij, and βii is, correspondingly, the linearity, interaction, and exponential parameters. The research's multiple regressions (aspects) are indicated by the symbol y_i. Linear regression optimization was used to determine the explaining factors' (y_i's) optimum parameters. To assess the variance evaluation, a statistical analysis of the model was completed (ANOVA). Experimentation planning and dataset evaluation were conducted using MATLAB 7.0.0 application.

2.4. Examination using gas chromatography (GC)

The percentage of fatty acids methyl esters, or FAME, in the biofuels that has been produced was determined using GC. Using an HP 6890 combination with a flame ionization device and an HP-50 capillary section, the study was carried out. The gas flow used was four ml. of pressurized air per min. The splitting ratio is 1:50, the heating protocol is 80-240°C at a fixed rate of 5oC/min, and the injector and sensors sensitivity were both 250°C. The standard error is 1 L. The identification of the FAME was established by employing an electrophoresis standards combination of identified FAME.

2.5. Physical properties assessment of biofuels and its combinations with petroleum diesel fuel

Using the industry-accepted analytical techniques for liquid fuels developed by the American Society for Testing and Materials (ASTM), the pure output created by oil esters was assessed for its estimation and evaluation of its gasoline parameters. The findings were contrasted to Egyptian hydrocarbon requirements, as well as European and American plant criteria (EN14214 and D-6751, accordingly). 3 spore composites were created by mixing biofuel with hydrocarbon in quantities of 96% by quantity, and their microbiological properties were examined. An Egyptian hydrocarbon sample and American standards for spore components are used to evaluate the results (D-7467, separately). The results are established by re-evaluating all criteria, and they are demonstrated above the total average**.**

Table 1: Biodiesel yield empirical and anticipated data are included in the design of the experiments sheet

Factors/Levels										
	Bio-diesel yield (wt%)		**Type of WCO X_4**		**CaO (wt %)X 2**		**CaO (wt%)X2**		**M:O (Molar ratio) X1**	
Run number	**Experimental**	**Predicted**	**Code value**	**Actual value**	**Code value**	**Actual value**	**Code value**	**Actual value**	**Code value**	**Actual value**
1	79	77.9	2	WFSO	3	9	3	120	3	12:1
2	88.5	90	1	WFCO	3	9	3	120	1	6:1
3	75	76.7	3	WFO	3	9	2	60	2	9:1
4	82.9	83.2	2	WFSO	3	9	1	30	1	6:1
5	76	76.09	3	WFO	2	6	3	120	1	6:1
6	74.3	75.9	3	WFO	3	9	1	30	2	9:1
7	83.5	83.7	2	WFSO	2	6	1	30	2	9:1
8	85.4	87	1	WFCO	1	3	1	30	3	12:1
9	91	90.3	1	WFCO	1	3	1	30	1	6:1
10	88.4	89.1	2	WFSO	1	3	2	60	1	6:1
11	84	82.9	1	WFCO	2	6	3	120	2	9:1
12	91	93	2	WFSO	1	3	3	120	2	9:1
13	78	77.5	3	WFO	1	3	3	120	3	12:1
14	81	79.9	3	WFO	2	6	1	30	3	12:1
15	90.3	88.95	1	WFCO	2	6	2	60	3	12:1

3. Results and Discussions

3.1. Analyzing the collected WCO physically and chemically

Microbiological properties of the gathered WCO should be studied since they will affect the form of biofuels that is generated. Table 2, evaluation of the gathered WCO's surface chemistry. Describe the characteristics of the WCO that were gathered. WFO has the following properties at different temperatures: densities at 15.56oC, surface tension at 40oC, total soluble soil quantity, extractive values, peroxide value, and molar mass, in both: 0.9328 g/cm3, 65cSt, 2.16 mg KOH/g oil, 221 mg KOH/g oil, 101 mg I2/100g oil, and 856.37. The values for WFSFO and WFCO, on the other hand, are almost identical, obtaining values of 0.9218 and 0.9204 g/cm3, 36.5 and 33.2cSt, 1.83 and 1.31 mg KOH/g oil, 171 and 187 mg KOH/g oil, 124 and 124 mg I2/100 g oil, and 886.77 and 896.82, accordingly.

3.2. Demonstrating the specified econometric model's validity

The objectives of statistical analysis were fitting the econometric formula, selecting a sample of quantitative elements, defining expected values, and determining the optimal values of the constituents to provide the maximum response. An empirical regression model was used using a grand masters formula to further recognize the connections between the explaining components and responses as the outcome has been the percentage production of spore.

$$Y = 35.92 - 5.3327X_1 + 7.4808X_2 + 3.9312X_3 - 1.9945X_4 - 5.433\,X_1X_2 + 0.357X_1X_3 - 3.0198X_1X_4 + 0.1748X_2X_3 + 15.119X_2X_4 - 0.3617X_3X_4 + 3.67X_1^2 - 5.864\,X_2^2 + 0.0028X_3^2 + 4.827X_4^2 \quad (3)$$

The coefficient of determination R2 must be near to zero for a perfect pairing solution, it is advised. As a result, the determiner's coefficients were measured to assess the reaction variance. The fitting model's R2 level of 0.9379 demonstrated that the empirical variables may be held responsible for 93.79% of the overall variance in responses. That validates the quality of fitting and verifies the analysis model's suitability. The quadratic formula model's F proportion and P - values were found to be 815.918 and 0.0001, accordingly, demonstrating the significance of the model at a 95% level of certainty. Figure 1.a shows the projected results for the percent yield of biodiesel compared to the experimental data with an R2 value of 0.9624. The variables that were anticipated and those that were measured agreed rather well (R2 value around unity). They show that the facts and forecasts are well congruent, and the hypothesis was effective in providing a precise estimation of responses for the devices inside the range of observations.

Also, examinations of the model's regressions were conducted to confirm its suitability. This disparity between the actual reaction and what was projected is known as the residue. Using the covariance advanced reporting rerelease, the investigation was assessed Figure1.b. As shown by the presence of a tendency in the residual distributions for the estimated parameters of the dependent variables, the equation properly captures the hyphen yield throughout the exploratory region. This indicates that the fitting is of exceptional quality. Analysis of variance (ANOVA) was used to determine the modeling components' statistically significant at the 95% level of assurance. Table 3, Using t- and p-values, every parameter's significance (coefficient) was evaluated. Demonstrate that the primary, significant statistical effects were caused by the direct effects of the M:O and catalyst dose as well as the interactions between the effects of reaction conditions and the kind of WCO substrates. Process duration had an additive influence with M:O on the transesterification process that was statistically important. Nevertheless, there are no discernible impacts on the transesterification from the interactions between catalytic dosage and reaction conditions, as well as between the kind of WCO feedstock and processing speed.

3.3. Impact of employing various WCO varieties on the activities of CaO

An ANOVA has been performed to investigate the effect of using different types of WCO material on the yield percentage of spore generated during the gasification. In a conventional ANOVA, the total of squared (TS), explanatory variables (EV), average numbers (AN), statistical technique, and p-value are shown. Considering the information included in Table 4 of the dataset. The WFSFO, WFCO, and WFO kinds of oil were employed, and the modest p-value of 0.0012 shows that their effects on the biofuel output are considerably different from one another. The facts presented in Tables 1 and 3 are further supported by the statistical analysis using ANOVA**.**

3.4. Productivity improvement for transesterification

To reach the intended maximum response (% yield of bio-diesel from WFCO as the suggested kind of WCO biofuels inside the examined study region), the functional limitations (values) of the predictors may be set in the experiment using the reactive optimization method offered in the IJCBS application.

3.4.1. Impact of the M:O molar ratio

The extra formaldehyde above M:O 10.57:1.0, caused a modest rise in the reaction, even though the anticipated outcome was not significantly higher than that of 94.873%, based on the process variables optimization. Consequently, it seems sensible to take the ideal level M:O 10.57:1 into account to minimize process-related additional expenses. As a greater molar M:O ratio is unfavorable for output purifying during the differences procedure. Also, recovering the surplus formaldehyde will use quite a lot of fuel.

Table 2: Physical and chemical characteristics of gathered WCO

Oil type parameters	**WFCO**	**WFO**	WFSFO
Density @15.56ºC,g/cm^3	0.9204	0.9328	0.9218
Viscosity@ 40ºC, cSt	33.2	65	36.5
Acid number overall, mg KOH/g	1.31	2.16	1. 83
Iodine number mgI_2/100g	124	101	124
Saponification value mg KOH/goil	187	221	171
Molecular weight	896.82	856.37	886.77

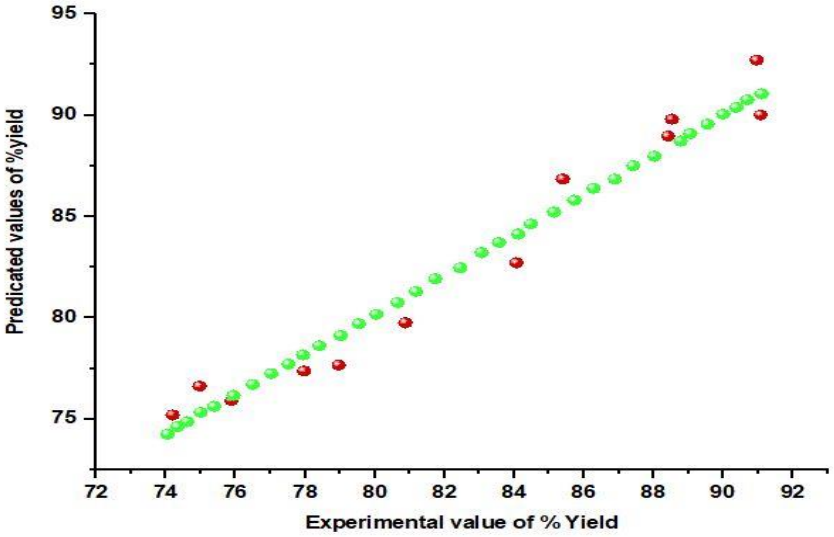

Figure 1 (a): model-specific feature

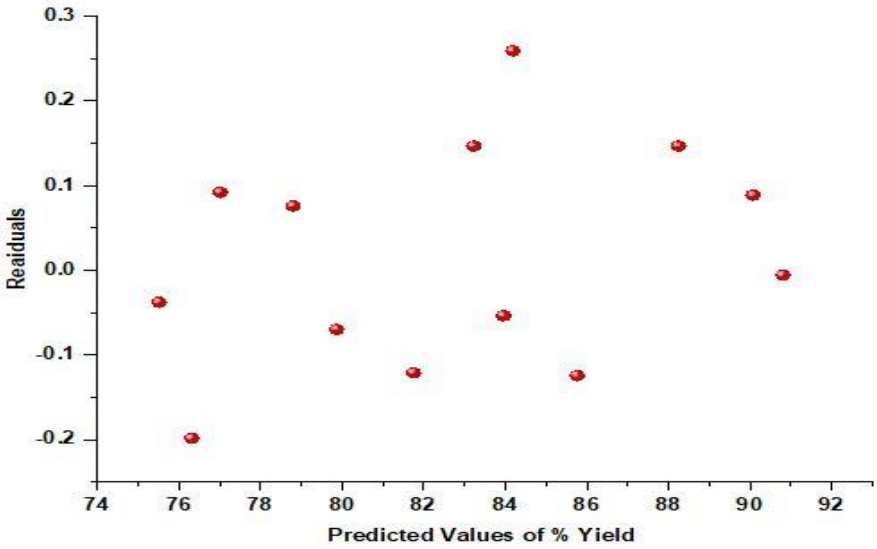

Figure 1 (b): Model's process based on biofuels

Table 3: Relevance of the parameter estimation

Exemplary phrase	Measurement estimations	p-value	t-value	Significant level
X^{2}_{1}	3.67	0.198	-0.004	Not significant
X^{2}_{2}	-5.864	0.0231	2.17	Significant
X^{2}_{3}	0.0028	0.674	-18.80	Not significant
X^{2}_{4}	4.827	0.0331	0.01	Significant
X_1	-5.433	0.001	-22.78	Highly significant
X_2	0.357	0.00001	35.05	Highly significant
X_3	-3.0198	0.0393	-12.89	Significant
X_4	0.1748	0.0126	-10.64	Significant
X_1*X_2	-5.433	0.0210	19.79	Significant
X_1*X_3	0.357	0.0645	0.06	Slightly significant
X_1*X_4	-3.0198	0.03074	-12.03	Significant
X_2*X_3	0.1748	0.0817	0.02	Not significant
X_2*X_4	15.119	<0.0001	54.07	Highly significant
X_3*X_4	-0.3617	0.872	-0.004	Not significant

Table 4: ANOVA table for examining the impact of various WCO feedstocks on the activity of CaO

Source	AN	EV	TS	Pro b>F	F
Groups	162.054	2	324.108	0.0012	12.42
Error	13.048	12	156.576		
Total		14	480.684		

Table 5: The discovered fatty acid methyl esters (FAME) are listed below

oil type	WFCO	WFO	WFSFO
	wt.%	wt.%	wt.%
Methyl ester of phenol acids (C16:0)	9.74	24.36	8.9
Esterifies diethyl acid (C18:0)	2.7	46.35	4.3
Melt-added acids (C18:1)	19.7	24.68	19
Linoleate of diethyl acids (C18:2)	67.9	4.61	67.8
Saturated FAME	12.4	70.71	13.20
Unsaturated FAME	87.6	29.29	86.8

Table 6: Biofuel generated from WFCO utilizing CaO compares to worldwide biofuel requirements and Egyptian biodiesels norms

Test	Unit	Bio-diesel lD-6751	Bio-diesel (EN14214)	Egyptian perto-diesel standards	Produced bio-diesel
Density @15.56ºC	g/cm^3	----	0.9-0.86	0.87-0.82	0.8902
Motion viscosity @40ºC	cSt	1.9-6	3.5-5	1.6-7	5.68
Pour point	^oC	----	----	4.5	-3
clouds reference	^oC	----	----	----	0
Combined acid value	mg KOH/g	<0.8	<0.5	Nil	0.5
Total S	wt%	< 0.05	< 0.01	<1	Nil
Water content	ppm			1500	151
Flash point	^oC	> 130	> 101	>55	155
Calorie content	MJ/Kg	----	32.9	> 44.3	39.51
The c-value	-	>47	>51	>55	44
Chlorine levels	mgI_2/100g	Bio-diese lD-6751	< 120	----	102

Table 7: Comparing blends' physical-chemical properties to B6-B20 biofuel mix specifications and Egyptian hydrocarbon samples

Test	Unit	Bio-diesel blends ASTMD-7467	B20	B10	B6	ASTMD-7467 biofuel mixes
Density @ 15.56ºC	g/cm^3	---	0.870	0.854	0.843	---
Motion viscosity @ 40ºC	cSt	1.9-4.1	4.51	4.44	4.40	1.9-4.1
Pour point	^oC	---	0	3	3	---
clouds reference	^oC	---	3	3	6	---
Combined acid value	Mg KOH/g	<0.3	0.5	0.47	0.45	<0.3
Total S	wt%	< 0.05	0.4	0.65	0.72	< 0.05
Water content	Ppm	---	120	105	95	---
Flash point	^oC	>52	96	86	78	>52
Calorific levels	MJ/Kg	---	42.00	43.31	44.88	---
Cetane number		>40	49.42	57.03	59.80	>40

3.4.2. The impact of CaO concentration

The appropriate computed coefficients in this respect demonstrated a beneficial correlation between the model and uses of catalyst concentration and the response. Similarly, a catalytic dosage of 6.73 wt% resulted in the best output of biofuels. As the optimum catalyst dose seemed to be enough, raising the catalyst dose would not only reduce the performance but also increase the cost of the transesterification.

3.4.3. Response time has an impact

It was determined that the low p-value quadratic component for response time was a meaningful factor. This implies that as response time rose, a higher yield of biofuels will be created. Among the most crucial elements determining the biodiesel manufacturing process is the methyl ester molecular proportion. Even though however the molar ratio calls for three moles of methanol to be added for every molecule of petroleum, this practice is frequent in an attempt to change the equilibrium of the transesterification method in the way of biodiesel bioethanol production. The higher alcohol concentration, up to 10.55:1, actually shifted the stability of a process to the positive side by stimulating the emergence of starting materials molecules on the CaO's topmost layer. Even so, substantially raising the M:O molar ratio to 12:1 did not aid the procedure. Since there were more total catalytically active lots of websites for the process with the rise in CaO concentration up to 6.73%, the yield of biodiesel (weight%) improved. The mass transfer between the reactants and catalyst is also said to have an impact on the FAME yield. In light of this, high catalytic concentrations result in a more fluid reagent combination, which, as a consequence of its mass charge

transfer, slows down the reaction temperature and, as a result, reduces the yield of FAME. The ideal M:O for soybean transesterification at 65oC, is 12:1. To transesterify WCO, utilized 12:1 M: O.

3.5. The biodiesel fuels generated from the WCO substrate have a FAME component.

The FAME content of the biofuels described in Table 5. Using 71% and 29% of saturated and unsaturated FAMEs, accordingly, biodiesel produced from WFO have a better adsorption FAME concentration as biodiesel manufactured from WFSFO and WFCO. Despite presenting typical saturated and unsaturated FAMEs for WFSFO and WFCO of 12.8% and 87.2%, respectively, these are nearly similar in structure.

3.6. The physical and chemical analysis of the biofuels generated by WFCO after increasing efficiency

The achieved % biodiesel output is 95% when the abovementioned ideal circumstances were used. According to Table.6, the generated bio-diesel was assessed based on its gasoline qualities in comparison to Egyptian petro-diesel and worldwide spore criteria. The biofuel that was created satisfies many requirements along with all entirely appropriate qualities. As an alternative to petro-diesel and a practical fuel, it may therefore be rated. With the WFCO and generated biofuels, the iodide level, which is a measurement of oil unsaturated fatty acid level, was recorded at 121 and 102 mg I2/100 g, accordingly. Monosaturated fatty acid ratio has a substantial impact on oil's susceptibility to oxidation. EN 14214 mandates that substances used as petroleum have an iodide level less than 120 g I2/100g sample.

3.7. Physical-chemical characteristics of the mixture

In order to satisfy the Egyptian petroleum diesel sample and ASTM standard specifications of B6-B20 (ASTM D-7476), hybrids of the produced biofuel and petrodiesel was made. The results of this evaluation are shown in Table 7. Analysis shows that as the volume % of bio-diesel grew, so did density and viscosity. These specifications are also in line with Egyptian hydrocarbon requirements, which might improve hydrophilicity. While the TAN of B100 dropped after mixing, the readings in the created blends are still greater than Egyptian hydrocarbon requirements and samples, as well as somewhat greater than the requirements for suggested spore mixtures.

4. Conclusions

WFCO and WFSFO are preferred as WCO feedstocks over WFO, which may be explained by their chemical structure and physical-chemical. It is advised to do further study to determine how the elemental composition of biodiesel affects enzymatic hydrolysis. The findings demonstrate a considerable impact of temperature range on catalyst production. The catalysis that produced the greatest catalytic properties for WCO-based biofuels generation was created at a crystallization temperature of 900 °C. The synthesis of biofuels is both affordable and environmentally safe when used cooking oil waste as the substrate and chromium CaO as the catalyst support. Also, this will assist with the correct use of WCO and resolve the problem of air pollution.

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