Applications of Statistical Approach in Prediction of Regression Model of Waste Cooking Sunflower Biodiesel

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ABSTRACT

The waste cooking oil is now a day’s useful for production of biodiesel through trans-esterification process with the help of magnetic/mechanical stirring. Therefore an attempt is made to create regression model of waste cooking sunflower biodiesel by applying response surface methodology. The nature of regression model is found to be quadratic in nature and all the statistical parameters are observed to be in desired range.

Keywords: waste cooking sunflower biodiesel, response surface methodology, trans-esterification, regression model

1. INTRODUCTION

The optimum trans-esterification process parameters were predicted by utilizing GA, ANN based evolutionary techniques by few researchers (Dhingra et al., 2013a; Dhingra et al., 2013b; Dhingra et al., 2014a; Dhingra et al., 2014b; Dhingra et al., 2014c; Dhingra et al., 2014d; Dhingra et al., 2016a; Dhingra et al., 2016b). These techniques are found to be reliable, accurate and fast as compared to mathematical modelling techniques due to programming based optimum value of response. The coupling of two or more techniques is called hybridization. Literature review indicated that hybridized techniques are more reliable than individual optimization techniques. The data taken from one technique is used by another approach for predicting more precise value of responses. Efforts made by researchers to utilize the hybridized techniques are discussed below:
Izadifar (2005) applied artificial neural network (ANN) to predict total trans- isomer content (produced during vegetable oil hydrogenation) as well as oleic acid, linoleic acid, linolenic acid content using multi-layer back propagation training algorithms. The eight variables (reaction temperature, H₂ pressure, catalyst concentration, mixing rate, iodine value and initial unsaturated fatty acid contents) were considered as inputs to ANN model. The neural model was trained, tested and evaluated from various experimental data obtained from pilot-plant hydrogenation reactor and using these data the network generalization was evaluated. Comparison of actual and predicted results showed the authenticity of predicted neural model.

Kumar and Bansal (2007) examined seven neural network architectures, three training algorithms along with ten different sets of weight and biases to predict various properties (flash point, fire point, viscosity and density) of diesel-soybean biodiesel blend (prepared from trans-esterification with methanol in the presence of alkaline catalyst). The results showed that an architecture 2-7-4 with Lavenberg-Marquardt (LM) training gave the best estimation of properties for diesel-biodiesel blend.

Rajendra et al. (2009) applied hybrid ANN-GA for predicting best pre-treatment process parameters in order to bring down the free fatty acid (FFA) levels of oil mixture (mahua and simarouba). Acid pre-treatment followed by main base trans-esterification reaction was developed to enhance biodiesel yield at a reaction temperature of 60°C. Biodiesel conversion of more than 90 % was observed by gas chromatography (GC). The important fuel properties were also found to be closer to commercial diesel and biodiesel standards.

Fahmi and Cremaschi (2012) developed ANN model for the optimization of biodiesel synthesis plant i.e., the one that gives the minimum net present sink. Various data were trained through ANN to reduce the computational cost of solving the resulting disjunctive programming through surrogate models. The total net present sink of about $41 million was obtained with difference of less than one percent from the results obtained by simulator. Shahbaz et al. (2012) examined glycerol removal in the production of biodiesel by the use of artificial neural networks (ANNs). Training was done on Lavenberg-Marquardt (LM) optimization method at feed forward neural network with 4 hidden neurons. The results from ANN were in agreement with actual one and an average deviation of 6.46 % was observed.

Stamenkovic et al. (2013) compared RSM and ANN models in terms of predictive, generalization and optimization abilities. The non-linear behavior through ANN was predicted better in comparison to RSM model while sensitivity analysis and optimization were evaluated better in RSM. The results showed an average biodiesel yield of 98.6 % at 12:1 ethanol to oil molar ratio, reaction temperature between 50° to 59°C, catalyst loading of 0.75 % (based on oil weight) and reaction time of 15 minutes.
Betiku et al. (2014) considered neem (*azadirachta indica*) oil for mathematical modeling and process parameters optimization of biodiesel through artificial neural network and response surface methodology. RSM was used in the pretreatment process of neem oil for the reduction of free fatty acid less than 1% by experimental design. Artificial neural network (ANN) combined with response surface methodology was then used for optimum biodiesel production at particular trans-esterification process variables. The experimental results were closer to the predicted results from RSM and RSM-ANN techniques which showed authenticity of the developed models. The fuel properties were also within the limits of ASTM D6751 and DIN EN 14214.

Betiku and Ajala (2014) considered thevetia peruviana (*yellow oleander*) oil for biodiesel production via Musa paradisiacal (plantain) peels as heterogeneous base catalyst. Response surface methodology was adopted in the pre-treatment process of to reduce the FFA content (1.72 mg KOH/g) and RSM-ANN was applied in the trans-esterification process for biodiesel synthesis (94.87%). The optimum conditions for RSM and hybrid RSM-ANN were: 0.35 v/v methanol to oil molar ratio. 1.5 hours reaction time in the presence of 3% w/v catalyst concentration and 0.3 v/v methanol to oil ratio, 1.25 hours reaction time in the presence of 2.8% w/w catalyst concentration respectively. The properties of produced biodiesel were within the range of ASTM D6751 and DIN EN 14214 standards. The same techniques were applied to waste goat tallow oil for production of biodiesel by Chakraborty and Sahu (2014).

Patle et al. (2014) experimentally investigated esterification and trans-esterification of waste cooking palm oil with methanol in the presence of sulphuric acid and sodium hydroxide respectively. These processes were simulated in Aspen plus simulator and a non-dominated sorting genetic algorithm II were applied to achieve the required objectives (profit, heat duty and organic waste). The results showed that process having three trans-esterification reactors was of lower organic waste (by 32%), less heat duty (by 39%) and slightly more profitable (by 1.6%) than process having single trans-esterification reactor. Table 2.2 shows the summary of various researchers who have used techniques (OFAT, GA’s, ANN etc.) other than RSM for optimizing the process parameters for enhancing the biodiesel yield. It can be concluded from the literature review that the optimization of biodiesel production is the most desirable objective for further enhancing the biodiesel yield.

2. REGRESSION ANALYSIS

The present work concentrates on the analysis of main experimentation in predicting the optimized trans-esterification process parameters for enhancing the biodiesel yield. To check the adequacy of the model and to predict non-linear regression analysis using ANOVA, Design Expert 6.0.8® software is used.
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Table 1 shows the model summary various biodiesels produced in the present study. To verify the adequacy of the predicted models, ANOVA has been applied. The significance of models are explained by ‘p’ test as shown in table 1. Those regression equation terms are significant whose p-values are less than 0.05.

By analysing the coefficient of determination ($R^2$), the goodness of fit is checked. The value of $R^2$, adjusted $R^2$ and predicted $R^2$ closer to each other (near to 1) indicates that the response models are significant. The precision index values of different response models for all the biodiesels produced except jatropha are shown in table 2. Adequate precision is a measure of signal to noise ratio and value greater than 4 shows better precision and reliability of the experiments. Standard deviation and coefficient of variation (C.V) are also observed to be in desirable range for various biodiesel models. The mathematical models for biodiesel yield of waste cooking sunflower oil as predicted by RSM is shown in equation 1.

Each term of the biodiesel model has been checked for significant test (p- test).

Table 1: Probability values (p-values) of each model and term for various biodiesels using analysis of variance (ANOVA)

<table>
<thead>
<tr>
<th>Source</th>
<th>Waste cooking Sunflower</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>EC</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Rt</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>RT</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>CC</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>MS</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>EC$^2$</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Rt$^2$</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>RT$^2$</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>CC$^2$</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>MS$^2$</td>
<td>0.2558</td>
</tr>
<tr>
<td>EC×Rt</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>EC×RT</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>EC×CC</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>EC×MS</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Rt×RT</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Rt×CC</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Rt×MS</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>RT×CC</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>RT×MS</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>CC×MS</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Lack of fit</td>
<td>&gt;&gt;&gt;0.05</td>
</tr>
</tbody>
</table>
### Table 2: Precision index values of regression models of various biodiesels produced

<table>
<thead>
<tr>
<th>Model</th>
<th>Precision index values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$R^2$</td>
</tr>
<tr>
<td>Waste cooking sunflower</td>
<td>0.99</td>
</tr>
</tbody>
</table>

**WCSBY (wt. %) = 945.83 – 11.16×EC – 12.68×Rt – 19.57×RT +21.20×CC – 0.32×MS – 0.10×EC$^2$ + 0.012×Rt$^2$ + 0.099×RT$^2$ + 4.93×CC$^2$ + 0.22×EC×Rt + 0.17×EC×RT – 2.41×EC×CC + 5.58×10$^{-3}$×EC×MS + 0.104×Rt×RT + 0.13×Rt×CC + 4.65×10$^{-3}$×Rt×MS + 0.90×RT×CC + 3.41×10$^{-3}$×RT×MS – 0.08×CC×MS …(1)

Where **WCSBY** shows waste cooking sunflower biodiesel yield

### 3. CONCLUSION

i. Significant regression model is developed by the use of response surface methodology based on CCRD

ii. Waste cooking sunflower biodiesel can be used to run the diesel engine by blending with diesel

### REFERENCES


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