**Design of Experiments (BBD)**

**Table 1**: Selected factors and levels for experimental design

|  |  |  |  |
| --- | --- | --- | --- |
| **Factors** | **Levels** | | |
| **-1** | **0** | **+1** |
| Temperature (°C) | 350 | 450 | 550 |
| Residence time (min) | 30 | 60 | 90 |
| Stirring speed (rpm) | 5 | 10 | 15 |

**Table 2:** Experimental design

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **DOE #** | **Factors / Parameters** | | |  |  | |
| **Temperature (°C)** | **Residence time (min)** | **Stirring speed (rpm)** | **Bio-oil**  **Collection(g)** | **Biochar**  **Collection(g)** | **Bio-oil %** |
| 1 **EX-5**  *(22/6/2023)*  2 **EX-4**  *(22/6/2023)* | 450 | 30 | 15 | 315 | 940 | 15.75 |
| 450 | 90 | 15 | 503 | 940 | 25.15 |
| 3 **EX-15** *(05/7/2023* | 350 | 60 | 5 | 377 | 1250 | 18.85 |
| 4 **EX-8**  *(27/6/2023)*  5 **EX-9**  *(27/6/2023)* | 550 | 30 | 10 | 457 | 998 | 22.85 |
| 550 | 90 | 10 | 691 | 998 | 34.55 |
| 6 **EX-2** *(20/6/2023)* | 550 | 60 | 15 | 690 | 955 | 34.50 |
| 7 **EX-12** *(03/7/2023)* | 450 | 60 | 10 | 502 | 902 | 25.10 |
| 8 **EX-13** *(04/7/2023* | 450 | 60 | 10 | 505 | 908 | 25.25 |
| 9 **EX-14** *(06/7/2023* | 450 | 60 | 10 | 511 | 899 | 25.55 |
| 10 **EX-6**  *(26/6/2023)*  11 **EX-7**  *(26/6/2023)* | 450 | 30 | 5 | 460 | 930 | 23.00 |
| 450 | 90 | 5 | 593 | 930 | 29.65 |
| 12 **EX-1**  *(19/6/2023)* | 350 | 60 | 15 | 500 | 1356 | 25.00 |
| 13 **EX-3**  *(21/6/2023)* | 550 | 60 | 5 | 575 | 1072 | 28.75 |
| 14 **EX-11**  *(28/6/2023)*  15 **EX-10**  *(28/6/2023)* | 350 | 90 | 10 | 460 | 1289 | 23.00 |
| 350 | 30 | 10 | 329 | 1289 | 16.45 |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **DOE #** | **Factors** | | | **Yield of bio-oil (%)** | | **Yield of biochar (%)** | **Yield of syngas (%)** |
| **Temperature (oC)** | **Residence time (sec)** | **Feedstock particle size (mm)** | **Actual** | **Predicted** |
| 1 | 450 (0) | 30 (-1) | 15 (1) | 38.26 | 38.66875 | 37.29 | 24.45 |
| 2 | 350 (-1) | 30 (-1) | 10 (0) | 33.69 | 33.61875 | 44.38 | 21.93 |
| 3 | 350 (-1) | 60 (0) | 5 (-1) | 35.68 | 35.665 | 42.87 | 21.45 |
| 4 | 550 (1) | 30 (-1) | 10 (0) | 37.85 | 37.42625 | 35.68 | 26.47 |
| 5 | 450 (0) | 60 (0) | 10 (0) | 42.56 | 42.78667 | 38.45 | 18.99 |
| 6 | 550 (1) | 90 (1) | 10 (0) | 38.92 | 38.99125 | 33.98 | 27.1 |
| 7 | 450 (0) | 90 (1) | 15 (1) | 39.98 | 39.89375 | 39.67 | 20.35 |
| 8 | 450 (0) | 60 (0) | 10 (0) | 42.87 | 42.78667 | 38.59 | 18.54 |
| 9 | 450 (0) | 30 (0) | 10 (0) | 42.93 | 42.78667 | 38.05 | 19.02 |
| 10 | 450 (0) | 30 (-1) | 5 (-1) | 40.23 | 40.31625 | 39.36 | 20.41 |
| 11 | 450 (0) | 90 (1) | 5 (-1) | 42.56 | 42.15125 | 38.54 | 18.9 |
| 12 | 350 (-1) | 60 (0) | 15 (1) | 34.62 | 34.2825 | 43.89 | 21.49 |
| 13 | 550 (1) | 60 (0) | 5 (-1) | 39.74 | 40.0775 | 34.98 | 25.28 |
| 14 | 350 (-1) | 90 (1) | 10 (0) | 34.69 | 35.11375 | 40.29 | 25.02 |
| 15 | 550 (1) | 60 (0) | 15 (1) | 37.54 | 37.555 | 35.68 | 26.78 |

450 90 15 39.98

450 30 15 38.26

450 60 10 42.56

550 90 10 38.92

550 60 15 37.54

350 90 10 34.69

450 60 10 42.87

450 30 5 40.23

450 60 10 42.85

550 60 5 39.74

350 30 10 37.85

350 60 5 35.68

450 90 5 42.56

550 30 10 37.85

350 60 15 34.62

**Coded Coefficients**

**Coded Coefficients**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Term** | **Coef** | **SE Coef** | **T-Value** | **P-Value** | **VIF** |
| Constant | 42.790 | 0.437 | 97.88 | 0.000 |  |
| Temperature (deg C) | 1.488 | 0.268 | 5.56 | 0.003 | 1.00 |
| Residence time (Min) | -0.117 | 0.268 | -0.44 | 0.679 | 1.00 |
| Stiring speed (rpm) | -0.553 | 0.268 | -2.06 | 0.094 | 1.00 |
| Temperature (deg C)\*Temperature (deg C) | -3.983 | 0.394 | -10.11 | 0.000 | 1.01 |
| Residence time (Min)\*Residence time (Min) | -1.468 | 0.394 | -3.72 | 0.014 | 1.01 |
| Stiring speed (rpm)\*Stiring speed (rpm) | -1.748 | 0.394 | -4.43 | 0.007 | 1.01 |
| Temperature (deg C)\*Residence time (Min) | 1.075 | 0.379 | 2.84 | 0.036 | 1.00 |
| Temperature (deg C)\*Stiring speed (rpm) | -0.155 | 0.379 | -0.41 | 0.699 | 1.00 |
| Residence time (Min)\*Stiring speed (rpm) | 0.540 | 0.379 | 1.43 | 0.213 | 1.00 |

Temperature (deg C) Residence time (Min) Stiring speed (rpm) Bio-oil (%)

350 30 10 37.87

350 60 5 35.66

450 60 10 42.89

450 90 5 39.78

450 30 15 38.29

550 60 15 38.15

450 60 10 42.59

450 60 10 42.89

550 60 5 39.77

350 60 15 34.66

350 90 10 34.66

450 30 5 40.27

550 90 10 38.96

450 90 15 39.96

550 30 10 37.87