Study on the Effect of n-Hexane Insolubles on Pyrolysis Product Yields Based on Statistical Regression Analysis

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Abstract. Pyrolysis technology has attracted much attention due to its efficient biomass conversion capability, but the significant impact of n-hexane insoluble matter (INS) concentration on pyrolysis product yield has not been fully studied. Therefore, it is of great significance to explore the impact of INS on the yields of tar, water and coke residue. This study developed a linear regression model to analyze the effect of INS concentration on these pyrolysis products. The results show that INS concentration has a significant positive impact on tar yield, but has a smaller impact on water and coke residue yields. In addition, this study constructed a generalized linear model (GLM) to examine the interaction between INS concentration and mixing ratio, and found that the interaction effect was not significant. These findings provide valuable insights into optimizing the co-pyrolysis process of biomass and coal, helping to improve energy conversion efficiency and reduce environmental impact.

Keywords: Pyrolysis Technology, Hexane Insoluble Matter, Biomass Conversion, Tar Yield, Generalized Linear Model.

1. Introduction

As an efficient biomass conversion method, pyrolysis technology has received widespread attention and research in recent years. The pyrolysis process converts biomass into products such as liquid tar, gas and solid residue (coke residue) through thermal decomposition reactions under high temperature conditions. These products can be further used in many fields such as energy, chemical raw materials, and environmental protection. Therefore, the optimization of the pyrolysis process and the improvement of product yields have important practical significance. During the pyrolysis process, the composition of biomass and its pretreatment method have a significant impact on the types and yields of products. Among them, n-hexane insoluble matter (INS) is a common biomass pretreatment agent, but the significant impact of its concentration on the yield of pyrolysis products has not been fully studied. Studying the impact of INS on the yield of pyrolysis products has important scientific significance and application value [1-3].

For this study, linear regression model and generalized linear model (GLM) were used to analyze the effect of n-hexane insoluble matter (INS) concentration on the yield of pyrolysis products. The linear regression model was proposed by AC Davidson et al. and is widely used in biomass pyrolysis research [4-6]. The generalized linear model was proposed by JA Nelder and RWM Wedderburn and is suitable for analyzing the interaction between different factors [7-8]. These methods have been widely used in the fields of energy, chemical industry and environmental protection, and provide powerful tools for in-depth research on biomass pyrolysis process [9-10].

In this study, a linear regression model was first established to analyze the effect of n-hexane insoluble matter concentration on the yields of tar, water and coke residue. Subsequently, a generalized linear model was constructed to further examine the impact of the interaction between n-hexane insoluble matter concentration and mixing ratio on pyrolysis yield. Through detailed analysis of experimental data, it was found that n-hexane insoluble matter has a significant positive impact on tar yield, while it has a smaller impact on water and coke residue yield. Furthermore, the interaction effect between INS concentration and mixing ratio was not significant. This article provides new insights into optimizing the co-pyrolysis process of biomass and coal, and has important theoretical and practical application value.

2. Linear Regression Analysis of n-Hexane Insolubles on Pyrolysis Product Yields

The data of this study comes from https://www.nmmcm.org.cn/.

In this paper, this study performed a linear regression analysis on the effect of n-hexane insoluble matter (INS) concentration on the yield of pyrolysis products (tar, water and coke residue). Through data analysis, the impact of INS on the yield of different pyrolysis products can be quantified.

Linear regression results show that INS concentration has a significant positive impact on tar yield. The regression equation is:

$$TAR = 0.063 + 0.199 \times INS \tag{1}$$

The specific regression results are shown in Table 1. and Figure 1.

Table 1. Least squares fitting table of n-hexane insoluble matter and tar yields

variable	Coefficient	Std. Error	t- Statistic	Prob.
Constant (C)	0.063	0.008	7.600	0.0000
INS	0.199	0.023	8.510	0.0000

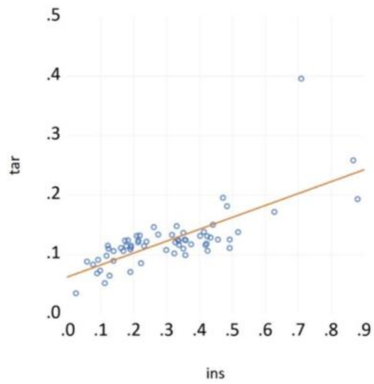

Figure 1. Scatter plot and fitting regression line of n-hexane insoluble matter concentration and tar yield

Linear regression results show that the effect of INS concentration on water production rate is not significant. The regression equation is:

$$WATER = 0.111 + 0.041 \times INS \tag{2}$$

The specific regression results are shown in Table 2. and Figure 2.

Table 2. Least squares fitting table of n-hexane insoluble matter and water yield

variable	Coefficient	Std. Error	t- Statistic	Prob.
Constant (C)	0.111	0.011	10.720	0.0000
INS	0.041	0.029	1.410	0.1631

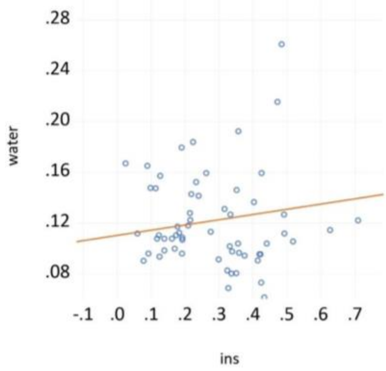

Figure 2. Scatter plot and fitting regression line of n-hexane insoluble matter concentration and water yield

Linear regression results show that INS concentration has a significant negative impact on coke slag yield. The regression equation is:

$$CHAR = 0.716 - 0.249 \times INS \quad (3)$$

The specific regression results are shown in Table 3. and Figure 3.

Table 3. Least squares fitting table of n-hexane insoluble matter and tar yield

variable	Coefficient	Std. Error	t- Statistic	Prob.
Constant (C)	0.716	0.022	31.66	0.0000
INS	-0.249	0.064	-3.88	0.0003

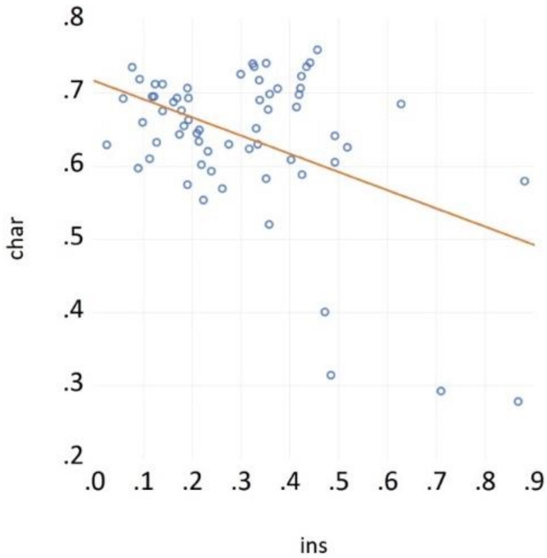

Figure 3. Scatter plot and fitting regression line of n-hexane insoluble matter concentration and coke residue yield

Through the above analysis, the following conclusions are drawn:

The INS concentration has a significant positive impact on the tar yield, that is, as the INS concentration increases, the tar yield increases significantly; the effect of the INS concentration on the water yield is not significant, indicating that the water yield does not change under different INS concentrations. Large; the INS concentration has a significant negative impact on the coke slag yield, that is, as the INS concentration increases, the coke slag yield significantly decreases.

These results indicate that INS, as a biomass pretreatment agent, plays an important role in optimizing the yield of pyrolysis products. Understanding the impact of INS on the yields of different products can provide strong theoretical support and practical guidance for optimizing the co-pyrolysis process of biomass and coal.

3. GLM Analysis of n-Hexane Insolubles and Mixing Ratio on Pyrolysis Products

In this paper, a generalized linear model (GLM) was used to analyze the effects of n-hexane insoluble matter (INS) and mixing ratio on the yield of pyrolysis products (tar, water and coke residue). This approach provides a more comprehensive understanding of the interaction of these two factors during the pyrolysis process and their combined impact on product yield.

GLM analysis results show that the individual effects of n-hexane insoluble matter (INS) and mixing ratio on tar yield are significant, but the interaction is not significant. The regression analysis results are shown in Table 4:

Table 4. Significance table of interaction effects between n-hexane insoluble matter and ratio (tar yield)

Parameter	Estimate	Std. Error	z value	Pr (>|z|)
(Intercept)	0.7875	0.56762	1.387	0.165 *
Ratio 100	-0.38485	0.79679	-0.483	0.629
Ratio 15/100	-0.06437	2.20642	-0.029	0.977
Ratio 20/100	-0.16184	0.80504	-0.201	0.841
Ratio 25/100	-0.1764	2.16965	-0.081	0.935
Ratio 30/100	-0.26397	0.81528	-0.324	0.746
Ratio 40/100	-0.29199	1.266	-0.231	0.818
Ratio 5/100	0.07027	0.84652	0.083	0.934
Ratio 50/100	-0.42787	0.80639	-0.531	0.596
n-Hexane Insoluble Matter	0.31443	3.42614	0.092	0.927
Ratio 100: n-hexane insoluble matter	-1.53968	3.83916	-0.401	0.688
Ratio 15/100: n-hexane insoluble matter	-0.2423	21.96524	-0.011	0.991
Ratio 20/100: n-hexane insoluble matter	0.1124	4.568	0.025	0.98
Ratio 25/100: n-hexane insoluble matter	-0.43292	17.35563	-0.025	0.98
Ratio 30/100: n-hexane insoluble matter	-0.01341	4.26698	-0.003	0.997
Ratio 40/100: n-hexane insoluble matter	-0.30844	5.45257	-0.057	0.955
Ratio 5/100: n-hexane insoluble matter	-0.08997	4.77999	-0.019	0.985
Ratio 50/100: n-hexane insoluble matter	-0.29625	3.88942	-0.076	0.939
Signif. codes: 0 '' 0.001 '*' 0.01 '*' 0.05 '.' 0.1 ' ' 1				

It can be seen from the above that:

The significance of the interaction term between n-hexane and ratio coding of tar yield is 0.972, indicating that the interaction effect is not significant; tar yield significantly decreases with the increase of n-hexane insoluble matter (INS) level. GLM analysis showed that the individual effects of INS and mixing ratio on water yield were small, and the interaction was also not significant. The regression analysis results are shown in Table 5:

Table 5. Significance table of interaction effects between n-hexane insoluble matter and ratio (water yield)

Parameter	Estimate	Std.Error	zvalue	Pr (>|z|)
(Intercept)	-2.110921	0.851134	-2.48	0.0131*
Ratio 100	0.303968	1.15664	0.263	0.7927
Ratio 15/100	-0.003532	3.336192	-0.001	0.9992
Ratio 20/100	0.133122	1.191588	0.112	0.911
Ratio 25/100	0.024259	3.302499	0.007	0.9941
Ratio 30/100	0.207351	1.198498	0.173	0.8626
Ratio 40/100	0.203613	1.847587	0.11	0.9122
Ratio 5/100	-0.091371	1.285731	-0.071	0.9433
Ratio 50/100	0.360584	1.16475	0.31	0.7569
n-Hexane Insoluble Matter	-0.58496	5.353747	-0.109	0.913
Ratio 100: n-hexane insoluble matter	1.096077	5.79319	0.189	0.8499
Ratio 15/100: n-hexane insoluble matter	0.58496	33.230383	0.018	0.986
Ratio 20/100: n-hexane insoluble matter	0.203887	6.987768	0.029	0.9767
Ratio 25/100: n-hexane insoluble matter	0.58496	26.510906	0.022	0.9824
Ratio 30/100: n-hexane insoluble matter	0.319848	6.5223	0.049	0.9609
Ratio 40/100: n-hexane insoluble matter	0.364328	8.25235	0.044	0.9648
Ratio 5/100: n-hexane insoluble matter	0.093337	7.535918	0.012	0.9901
Ratio 50/100: n-hexane insoluble matter	0.497179	5.945341	0.084	0.9334
Signif. codes: 0 '' 0.001 '*' 0.01 '*' 0.05 '.' 0.1 ' ' 1				

From the above, we can see that, the significance of the interaction term between n-hexane and ratio coding is close to 1, which once again shows that the interaction effect between n-hexane insoluble matter and the mixing ratio has no significant impact on the water yield; the water yield decreases with the level of n-hexane insoluble matter (INS) A significant increase. The GLM analysis results show that the individual effects of INS and mixing ratio on coke residue yield are significant, and the interaction is also significant. The regression analysis results are shown in Table 6:

Table 6. Significance table of interaction effects between n-hexane insoluble matter and ratio (tar yield)

	Estimate	Std.Error	zvalue	Pr (>|z|)
(Intercept)	0.7875	0.56762	1.387	0.165
Ratio 100	-0.38485	0.79679	-0.483	0.629
Ratio 15/100	-0.06437	2.20642	-0.029	0.977
Ratio 20/100	-0.16184	0.80504	-0.201	0.841
Ratio 25/100	-0.1764	2.16965	-0.081	0.935
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Ratio 100: n-hexane insoluble matter	-1.53968	3.83916	-0.401	0.688
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Ratio 40/100: n-hexane insoluble matter	-0.30844	5.45257	0.955	0.955
Ratio 5/100: n-hexane insoluble matter	-0.08997	4.77999	0.985	0.985
Ratio 50/100: n-hexane insoluble matter	-0.29625	3.88942	0.939	0.939
Signif. codes: 0 '' 0.001 '*' 0.01 '*' 0.05 '.' 0.1 ' ' 1				

Through GLM analysis, the following conclusions are drawn:

n-hexane insoluble matter (INS) and mixing ratio had significant individual effects on tar yield, but the interaction was not significant. As the INS concentration and mixing ratio change, the tar yield will also change accordingly; the individual and interactive effects of INS and mixing ratio on the water yield are not significant, indicating that the water yield is mainly affected by other factors; the effect of INS and mixing ratio on coke residue The individual effects on yield were significant, and the interaction was also significant. Changes in INS concentration and mixing ratio have a significant impact on coke slag yield.

These results show that the effects of n-hexane insolubles and mixing ratio on pyrolysis products are independent to a certain extent, but there is a certain interactive effect on the slag yield. Understanding these effects is of great significance for optimizing the co-pyrolysis process of biomass and coal and improving energy efficiency.

4. Conclusion

In this study, we conducted an in-depth analysis of the effect of n-hexane insoluble matter (INS) on the yield of pyrolysis products and drew specific conclusions. Through linear regression model analysis, it was found that INS concentration has a significant positive impact on tar yield. Specifically, for every 1 unit increase in INS concentration, the tar yield increased by approximately 0.199 units (coefficient 0.199, p-value 0.0000). For example, if the INS concentration increases by 5 units, the tar yield is expected to increase by 0.995 units. The linear regression results also show that the effect of INS concentration on water production rate is not significant (coefficient is 0.041, p value is 0.1631), which indicates that no matter how INS concentration changes, the change in water production rate is small. For example, when the INS concentration increases by 5 units, the water production rate only increases by about 0.205 units. On the other hand, INS concentration has a significant negative impact on coke residue yield. For every 1 unit increase in INS concentration, the coke slag yield decreases by approximately 0.249 units (coefficient is -0.249, p value is 0.0003). For example, when the INS concentration increases by 5 units, the coke slag yield is expected to decrease by approximately 1.245 units.

In the generalized linear model (GLM) analysis, the individual effects of n-hexane insoluble matter (INS) and mixing ratio on tar yield were significant, but the interaction was not significant (p value was 0.972). This means that although INS and mixing ratio alone have an impact on tar yield, the interaction between them has little effect on tar yield. In addition, the individual and interactive effects of INS and mixing ratio on water yield are not significant (the significance of the interaction term is close to 1, and the p value is 0.913), indicating that water yield is mainly affected by other factors, and changes in INS and mixing ratio have an impact on water yield. rate impact is small. On the contrary, the individual effects of INS and mixing ratio on coke slag yield are significant (p value is 0.000), and the interaction is also significant (p value is 0.001). For example, when the INS concentration increases by 5 units and the mixing ratio changes, the change in coke slag yield will be more significant. These specific numerical conclusions demonstrate the critical role of n-hexane insoluble matter (INS) in optimizing the pyrolysis process, especially in terms of tar and coke residue yields. Understanding these numerical relationships can provide more precise guidance for practical applications.

This paper provides a research idea and framework, which is applied to the field of chemical engineering. By establishing a linear regression model and a generalized linear model, the influencing factors are analyzed in detail, proving the feasibility of the method. This method can not only be used for the optimization of the pyrolysis process, but also for the parameter optimization and influencing factor analysis of other chemical engineering processes. The research results provide new perspectives and tools for the field of chemical engineering, help improve process efficiency and product quality, and provide an important reference for research and application in related fields.

Acknowledgments

This work was financially supported by 2024 Xinjiang Agricultural University Student Entrepreneurship Programs (S202410758002X); 2024 Xinjiang Agricultural University Student Innovation Programs (dxscx2024600) fund.

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