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Research article

Enhanced biofuel production from Sacha Inchi wastes: Optimizing pyrolysis for higher yield and improved fuel properties

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ABSTRACT

Sacha inchi waste consists of residues (SR) and shells (SS) that are processed into liquid fuel using a traditional pyrolysis process. Pyrolysis was performed at a constant heating rate of 20 °C/min and nitrogen flow rate of 100 mL/min. Before the process took place, a preliminary TGA analysis was performed and the results revealed that the appropriate pyrolysis temperature and time allowed a variation of 250–450 °C and 10–50 min, respectively. The results showed that the pyrolysis oil yields of both SR and SS increased with increasing pyrolysis temperature and time. However, the pyrolysis oil yield of SR was significantly higher than that of SS because the main component of SR contains abundant carbon from saturated fatty acids. The ANOVA method shows that the SS model is more complex and examines more terms and interactions, whereas the SR model is simpler and focuses on fewer components, but still shows significant effects, especially through temperature. The nonsignificant p-value for time in the SR model suggests that time may not have the same influence as temperature on the dependent variable. The SS pyrolysis oil was consistent and resulted in a constant calorific value and flash point between 31.10 and 32.14 MJ/kg and 120 and 124 °C, respectively. However, decreasing the O/C atomic ratio of SR pyrolysis oil from 0.92 to 0.38 influenced the increasing calorific value from 36.66 to 38.75 MJ/kg, while the H/C atomic ratio of SR pyrolysis oil was close to 2.00. This suggests that its effectiveness maintains an alkene structure that can improve fuel efficiency. The molecular formulae of the SS pyrolysis oil were $CH_{16}N_{0.04}O_7$ and that of SR pyrolysis oil was $CH_{2.2}N_{0.08}O_{0.45}$.

1. Introduction

Thailand is highly dependent on energy imports owing to its limited reserves of natural gas and petroleum. The trade balance of a nation is affected by its reliance on imported gas and oil, which exposes it to geopolitical risks and fluctuations in world prices. Thailand's economy is considerably affected by fluctuating oil prices, which can affect everything from product and service prices to transportation expenses. High oil prices can increase the operating expenses for businesses and living expenses for consumers. As an agricultural country, Thailand has plentiful biomass, which has a high potential for use as a liquid or solid fuel [1]. Many years ago, Sacha Inchi (*Plukenetia volubilis* L.) was imported from South America for breeding in Thailand, especially in the central region, as well as in other Southeast Asian countries [2]. Sacha Inchi, also known as the Inca peanut or Sacha peanut, originates in the Amazon

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rainforest. The plant is prized for its nutritious seeds, which are packed with proteins and omega-3, omega-6, and omega-9 fatty acids, making them a valuable source of essential fatty acids that are not commonly found in plants. In addition, these seeds are loaded with antioxidants and have high digestibility, offering numerous health benefits for humans. Sacha Inchi peel was separated from the kernel and extracted for oil production using mechanical devices until the residue was left off, and then the shell and residue were turned into Sacha Inchi waste (Fig. 1). Oil from the Sacha Inchi kernel consists of several chemicals, nutrients, and antioxidant agents [3,4]. The hydrophilic–lipophilic balance (HLB) of this oil is highly feasible for cosmetic and pharmaceutical applications [5]. However, little research has been conducted on how to effectively use the shells and residues left over from this process. The potential of shells and residues as sources of renewable energy through pyrolysis is comparatively underexplored, even though seeds and oils have been studied. Sacha Inchi shells (SS) and Sacha Inchi residues (SR), which were discarded from the oil extraction process, were used as efficient solid fuel in a drop tube reactor for gasification [6] and as an adsorbent and catalyst supporter [7,8]. However, SR applications have not been reported yet. Previous studies linking the results of these pyrolysis projects to national energy policies are lacking, especially in Thailand, where there has been a strong push to increase the consumption of renewable energy. To help meet renewable energy targets, research should examine how bio-oil from Sacha Inchi waste could be incorporated into the current energy framework.

Pyrolysis is used to process various biomass types, including organic municipal waste, forest waste, and agricultural residues. This adaptability makes it possible to use materials that would otherwise be discarded, such as safflower seeds [9], empty palm fruit bunches [10], Napier grass [11] and apple pulp [12] all of which support sustainable resource management and waste reduction. By converting biomass into stable forms of solid carbon and oil, which are useful energy sources, pyrolysis can significantly reduce overall greenhouse gas emissions, especially when compared to the decomposition of biomass in landfills, which produces methane, a potent greenhouse gas.

Based on this hypothesis, this study focused on the feasibility of producing pyrolysis oil from Sacha Inchi using laboratory-level equipment. Based on the TGA results, the pyrolysis temperature and residence time were chosen. The optimal values reported in previous studies were utilized to maintain constant values for other parameters, such as moisture content, heating rate, and particle size [13]. To identify important factors that influence the yield, such as pyrolysis temperature, residence time, and raw materials, the production yields from the pyrolysis process were also analyzed using the Analysis of Variance (ANOVA) method. ANOVA is useful for identifying variables that have a significant impact on yield as well as for illuminating the interactions between variables, which are crucial for optimizing operational parameters. To identify the ideal concentrations of important variables and evaluate the scalability of the process from laboratory to industrial scales, statistical validation was used to optimize the pyrolysis conditions. Additionally, ANOVA makes it easier to investigate the intricate relationships between variables, which improves the accuracy of forecasting models for biomass pyrolysis.

The final goal of this study was to identify the ideal pyrolysis conditions that would maximize the yield of pyrolysis oil, enhance the use of agricultural byproducts, and offer a sustainable substitute for traditional fuels. The most important variables in the pyrolysis process, such as temperature, residence time, and raw material properties, were determined through experimental analysis employing Analysis of Variance (ANOVA). This strategy aims to increase pyrolysis productivity and efficiency while also supporting Thailand's larger energy policy objectives.

2. Materials and method

2.1. Materials

Sacha Inchi residue (SR) and Sacha Inchi shell (SS) were supplied by the oil extraction process in Suphanburi Province, Thailand, as shown in Fig. 1.

They were separately dried in an oven at 105 °C for 8 h to remove moisture and then gridded to control the particle size to less than 2 mm. Notably, smaller particle size affects the product yield [14]. Subsequently, the ground sample was maintained under dry conditions before pyrolysis.

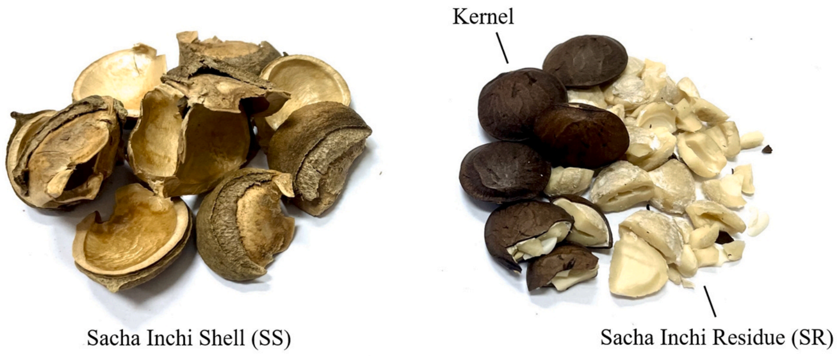

Fig. 1. Sacha Inchi wastes.

2.2. Production of pyrolysis oil

The pyrolysis instrument was set up in the laboratory using the basic device shown in Fig. 2. The pyrolysis process in the batch reactor is composed of the heating mantle for generating the heat duty by a constant heating rate of 20 °C/min. The gas product from pyrolysis was condensed via a condenser for liquid conversion. The feedstock was fed at 200 g per batch, and the nitrogen atmosphere was controlled using an N_2 flow rate of 100 mL/min, which is the general rate used in laboratory-scale pyrolysis [15]. The TGA results confirmed that the SR and SS were highly degraded at the range of 250–450 °C as shown in Fig. 3, which was consistent with other pyrolysis publications, such as rice straw [16] or the seed of an African star apple [17]. Thus, the pyrolysis temperature from 250 to 450 °C should be varied for 10–50 min to reach stable conditions. Each condition was performed three times to replicate the precision. The amount of pyrolysis oil was collected by weight measurement and evaluated as follows: pyrolysis oil yield (wt%) = (weight of pyrolysis oil/weight of total feedstock) × 100.

2.3. Statistical experimental data analysis

The pyrolysis oil production yield data were analyzed using Design Expert version 13 software (Stat-Ease Inc., Minneapolis, MN, USA) to determine the optimal conditions, analyze the variance using ANOVA, and prepare the response surface under a typical response for no transformation data ($\lambda = 1$). The corresponding models were adjusted using optimized production conditions to predict pilot-scale pyrolysis oil in the future.

2.4. Pyrolysis oil characterization

The pyrolysis oil was characterized using the American Society for Testing and Materials (ASTM) method as follows: ultimate analysis (ASTM-D5373) using a PerkinElmer CHN Elemental Analyzer (2400 Series II), calorific value (ASTM-D240), and flash point (ASTM-D6450).

3. Results and discussion

3.1. Characteristics of Sacha Inchi wastes

The Sacha Inchi shell and residue (SS and SR) were subjected to ultimate analysis (ASTM-D5373) to determine their basic components. The results show that SR and SS contain high levels of carbon and oxygen. These high-carbon results suggest that these materials can potentially be converted into carbon-dense materials, leading to higher energy densities. Conversely, a high oxygen content reduces the energy density of pyrolysis oil, and oxygen-containing compounds, such as acids and alcohols, can increase the reactivity and stability of pyrolysis oil over time. Balancing the carbon and oxygen contents is critical for optimizing the properties of pyrolysis oil for its intended application as a fuel or chemical feedstock. In terms of pyrolysis oil, carbon and hydrogen are the main components that affect the combustion reactions and should be considered.

Table 1 shows that the SR carbon and hydrogen contents were found at 62.70 % and 9.15 %, respectively, which were significantly higher than those in SS, with 50.71 % carbon and 6.11 % hydrogen content, respectively. Moreover, several agricultural materials delivered different chemical component contents, such as Giant Miscanthus [18] which showed 51.30 % carbon and 6.20 % hydrogen, oil palm mesocarp fiber [19] which showed 45.38 % carbon and 10.59 % hydrogen, and 47.50 % carbon and 6.00 % hydrogen were present in banana peel [20]. However, a higher carbon content (%) from the SR was achieved in this study, which should be assessed via the oil phase after pyrolysis. The results showed that SR and SS are interesting alternative energy sources for experiments, similar to oil.

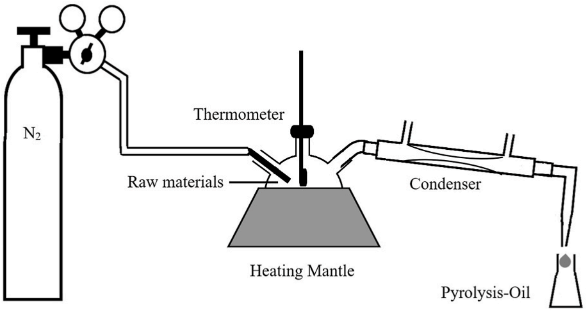

Fig. 2. Experimental setup for pyrolysis.

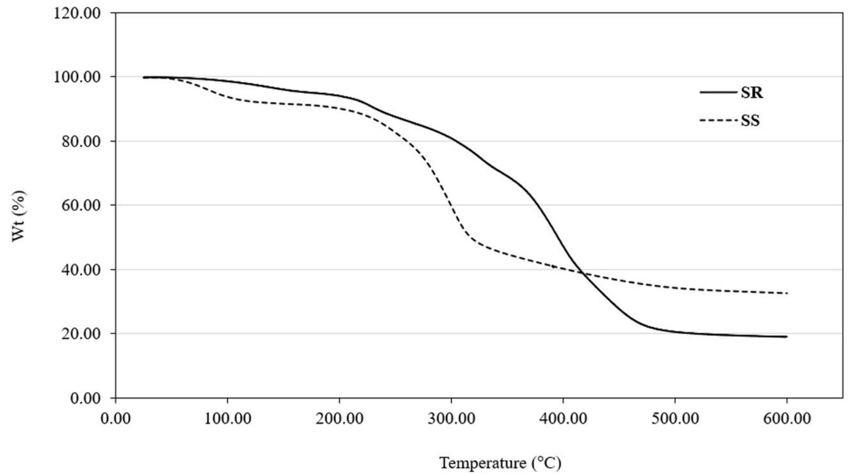

Fig. 3. Thermogravimetric analysis of Sacha Inchi wastes.

Table 1
Ultimate analysis of raw materials.

Materials	Ultimate analysis (wt%)			
	C	H	N	O[a]
SS	50.71	6.11	0.76	42.42
SR	62.70	9.15	4.91	23.24

[a] By difference.

3.2. Production yield of pyrolysis oil

The pyrolysis of the SR and SS was performed using the instrument set shown in Fig. 1. The pyrolysis temperature was maintained at 250–450 °C, while the pyrolysis time varied between 10, 20, 30, 40, and 50 min at a constant heating rate of 20 °C/min. The

Table 2
Pyrolysis oil yield from SS and SR (wt%).

Run	Temp (°C)	Time (min)	Oil-yield (%)			
			SS	SD-SS	SR	SD-SR
1	250	10	8.09	0.95	11.23	0.78
2		20	9.56	0.55	12.58	0.66
3		30	9.66	0.53	12.88	0.58
4		40	10.87	0.76	13.74	0.65
5		50	10.87	0.87	13.80	0.49
6	300	10	15.72	1.13	17.82	0.90
7		20	15.81	0.93	19.42	0.41
8		30	16.00	1.26	20.42	0.25
9		40	16.21	0.83	21.40	0.56
10		50	16.22	0.77	21.40	0.75
11	350	10	21.34	0.68	28.33	0.84
12		20	22.13	1.14	30.37	1.02
13		30	22.35	0.68	31.83	0.49
14		40	22.48	0.48	32.28	0.87
15		50	22.50	0.61	32.32	0.74
16	400	10	28.08	0.49	45.77	0.53
17		20	28.10	0.75	46.25	0.79
18		30	28.22	0.40	47.24	0.72
19		40	28.47	0.87	47.66	0.47
20		50	28.47	0.67	47.66	0.51
21	450	10	29.52	1.02	47.94	1.38
22		20	29.91	0.63	49.00	0.88
23		30	30.11	0.83	49.47	0.82
24		40	31.36	0.46	50.07	0.80
25		50	31.36	1.03	50.07	1.10

pyrolysis results are presented in Table 2. These results revealed that the SR oil yield was significantly higher than the SS oil yield. Because SR contained the saturated fatty acids index 6.74–7.70 while that of SS was 1.79 [21], this was consistent with the final analysis results and SR showed higher carbon content. However, the two raw materials showed the same positive trends in terms of pyrolysis temperature and time. This is because higher temperatures and longer periods affect heat accumulation within the material structure, causing abundant cellulose to decompose and convert into oil, gas, and carbon residues. Heat penetrates materials and gradually breaks down complex polymers, such as cellulose and lignin, into simpler compounds. The highest oil yield of SR was obtained at 50.07 at a temperature of 450 °C for 40 min of pyrolysis, whereas SS only had an oil yield of 31.36 under the same conditions. The different oil yields were reported using different raw materials, for example, an oil yield of 78 % was reported for rice bran wax [21], an oil yield of 47.7 % was determined for sawdust mixed with oil sludge [22] and 74.2 % came from loblolly pine crisps. However, not only did the oil yield indicate the success of pyrolysis oil production but also the fuel properties, as discussed in the next section.

3.3. *Statistical data analysis*

To increase the production yield of pyrolysis oil, analysis of variance (ANOVA) was used to analyze these data and solve and evaluate the essential parameters for improving production. Onokwai et al. used ANOVA to determine the effects of various operating parameters on product yield and properties. They reported that high F-values and low p-values indicated strong models with statistically significant effects on the investigated variables [22] The ANOVA results are presented in Table 3. The initial parameters were defined as A: temperature (250–450 °C) and B: time (10–50 min). The statistical experimental design analysis was divided into three types with one parameter (A, B) and two interactions (AB, A^2, and B^2). The probability of a 95 % confidence interval was limited to a P value of less than 0.05 (5 %), indicating significant or effective parameters related to the model. The SS model has a high F-value of 393.58 with a p-value <0.0001, indicating that the model is statistically significant and that parameters A and B, along with their interactions and quadratic terms, influence the prediction of oil yield. The temperature had a profound influence on the oil yield of SS, as evidenced by an F value of 1911.53 and a p-value <0.0001. This suggests that temperature is a critical factor in the pyrolysis process, while time also plays a significant role, although less pronounced than temperature, with an F value of 14.45 and a p-value of 0.0067. However, the interaction parameters AB and B^2 were not statistically significant, as indicated by the p-values of 0.4693 and 0.4814, respectively. The SR model had a high F-value of 220.93 with a p-value <0.0001, indicating that the model was statistically significant. However, it only includes the main effects of A and B without interactions or quadratic terms. Parameter A is a crucial factor in SR, with an F-value of 430.33, and a p-value <0.0001, but parameter B (time) has compared to temperature with an F-value of 3.94 and a p-value of less than 0.0753, indicating that it is not statistically significant at the 0.05 level.

Fig. 4(A) provides insight into the interaction effect between temperature and time on oil yield. The absence of a twisted or warped surface indicates that the interaction between the two variables was not highly significant, which is consistent with the statistical analysis in which the interaction term (AB) had a high p-value, suggesting that there was no significant interaction. Furthermore, the relatively smooth color transition on the surface from low to high yields suggests that the effects of temperature and time on the yield are relatively independent within the investigated range. According to the RSM curve, temperature was the dominant factor in the production of SS pyrolysis oil. There appeared to be an optimal temperature range in which the oil yield was maximized, beyond which the increase in yield reached a plateau. Time also affects yield, but in a less dramatic way, and the lack of a significant interaction between time and temperature suggests that the optimization of each factor could occur independently. The RSM curve of RS in Fig. 4 (B) shows a smooth transition from lower to higher yield values, suggesting that the interaction between temperature and time did not introduce significant complexity into the oil yield response. This is consistent with the hypothesized additive effect of these variables within the studied region, as the surface did not show any unexpected peaks or valleys, which would indicate complex interactions. The curve indicates that temperature is a critical variable for maximizing the pyrolysis oil yield, with a defined optimal range evident in the surface plot. Time also contributes positively to yield but does not have the same influence as temperature. The data points

Table 3
Analysis of variance parameters by ANOVA method.

Materials	Source	Sum of Squares	df	Mean Square	F-value	p-value
SS	Model	742.73	5	148.55	393.58	<0.0001
	A-Temp	721.46	1	721.46	1911.53	<0.0001
	B-Time	5.46	1	5.46	14.45	0.0067
	AB	0.2209	1	0.2209	0.5853	0.4693
	A^2	13.45	1	13.45	35.63	0.0006
	B^2	0.2087	1	0.2087	0.5529	0.4814
	Residual	2.64	7	0.3774		
	Cor Total	745.37	12			
SR	Model	2505.04	2	1252.52	220.93	<0.0001
	A-Temp	2439.7	1	2439.7	430.33	<0.0001
	B-Time	22.33	1	22.33	3.94	0.0753
	Residual	56.69	10	5.67		
	Lack of Fit	56.69	9	6.3		
	Pure Error	0	1	0		
	Cor Total	2561.73	12			

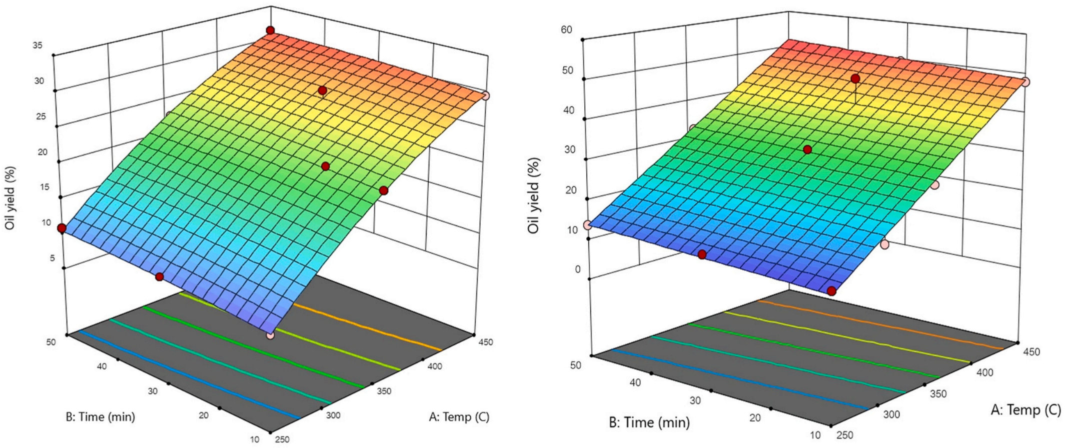

Fig. 4. RSM curves of pyrolysis oil production from (A) SS (B) SR.

marked in the diagram agree well with the modeled surface, indicating that the experimental setup effectively captured the response of the system.

3.4. *Pyrolysis oil characterization*

3.4.1. *Ultimate analysis of pyrolysis oils*

In Section 3.3, a significant parameter was determined for the pyrolysis temperature. Therefore, further investigation involves the analysis of pyrolysis oil from SR and SS at a pyrolysis temperature of 40 min, as shown in Table 4.

As shown in Table 4, all the parameters of the pyrolysis oil of SS were nearly constant in the final analysis data. The carbon content increased slightly with increasing temperatures and fluctuations in the range of 6.21–8.39 %, while the oxygen content remained slightly constant with increasing temperatures in the range of 80.52–81.91 %. Hydrogen and nitrogen were nearly constant at 10.69–12.88 % and 0.30–0.40 %, respectively. By contrast, the pyrolysis oil from the SR exhibited a different trend. Carbon content increased with increasing pyrolysis temperature. The maximum carbon content of 56.16 % was achieved at a pyrolysis temperature of 450 °C, while the oxygen content decreased with increasing temperature and had the highest volume of 47.23 % at 250 °C. Hydrogen and nitrogen were nearly constant at 8.05–10.28 % and 4.91–6.25 %, respectively.

Fuels with high O/C and H/C atomic ratios indicates the presence of C–O and O–H bonds. They refer to the carbonyl (–CO) and hydroxyl (–OH) groups contained in water, alcohol, or carboxylic acid. The H/C atomic ratio of SR pyrolysis oil was reported in the range of 2.20–2.75, which is similar to the alkene structure (C_nH_{2n}). Therefore, SR pyrolysis oil was more suitable for liquid fuel conversion than SS pyrolysis oil, which had an H/C atomic ratio of 15.20. The H/C atomic ratio of the pyrolysis oil from the SR decreased with increasing temperature, which is consistent with a previous report that used cherry pulp as the starting material [8]. When comparing the pyrolysis oil properties of different types of biomaterials (Table 5), the pyrolysis oil from this study showed a slightly higher calorific value than other materials, except the provided pyrolysis oil made of PE or petroleum-based materials had the highest calorific value such as natural gas (46.67 MJ/kg). The primary molecular formulae of the pyrolysis oil from the SR and SS were studied using a basic atomic ratio method, as previously reported [23]. The molecular formula of the SS pyrolysis oil was $CH_{16}N_{0.04}O_7$ and that of the SR pyrolysis oil was $CH_{2.2}N_{0.08}O_{0.45}$.

Table 4
Ultimate analysis of pyrolysis oil.

Materials	Temperature (°C)	Oil-yield (%)	Ultimate analysis (wt%)				Atomic ratio	
			C	H	N	O[a]	O/C	H/C
SS	250	10.87	6.21	12.88	0.30	80.61	9.74	24.89
	300	16.21	6.72	11.03	0.34	81.91	9.14	19.70
	350	22.48	7.41	10.98	0.38	81.23	8.22	17.78
	400	28.47	8.21	10.79	0.42	80.58	7.36	15.77
	450	31.36	8.39	10.69	0.40	80.52	7.20	15.29
SR	250	13.74	38.47	8.05	6.25	47.23	0.92	2.51
	300	21.40	41.55	9.52	5.47	43.46	0.78	2.75
	350	32.28	48.26	9.55	5.20	36.99	0.57	2.37
	400	47.66	52.79	10.06	5.09	32.06	0.46	2.29
	450	50.07	56.16	10.28	4.91	28.65	0.38	2.20

[a] By difference.

Table 5
Fuel properties of pyrolysis oil.

Properties	Calorific Value (MJ/kg)					Flash Point (°C)				
Temp (°C)	250	300	350	400	450	250	300	350	400	450
SS	32.14	31.88	31.72	31.53	31.10	121	120	122	124	122
SR	36.66	37.16	37.83	38.43	38.75	100	101	102	106	110

3.4.2. Fuel properties of pyrolysis oils

The pyrolysis oil prepared from SS and SR at a pyrolysis temperature of 250–450 °C for 40 min was analyzed for its fuel properties as shown in Table 5. The results showed that the calorific value of the SS pyrolysis oil decreased slightly with increasing temperature from 32.14 to 31.10 MJ/kg. In general, a higher content of C (carbon) and H (hydrogen) in a fuel is associated with a higher calorific value, owing to its high energy content. Although the C content of SS pyrolysis oil increased with temperature from 6.21 % to 8.39 %, the N content decreased again from 12.88 % to 10.69 % (Table 4). This could be one of the reasons for the slight decrease in the calorific value of the SS pyrolysis oil. By contrast, the SR pyrolysis oil showed a significant increase in calorific value with temperature owing to C, and the H content also increased significantly with temperature. Theoretically, reducing the oxygen (O) and nitrogen (N) contents is expected to have a positive effect on the calorific value because oxygen does not contribute to combustion but increases the mass of the fuel, and nitrogen is generally considered inert during combustion.

The fuel properties of SS and SR pyrolysis oil prepared at 400 °C in 40 min were also compared to examine the feasibility of fuel application. The fuel properties, including those of other liquid fuels, are listed in Table 6. Both the SS and SR pyrolysis oils exceeded the minimum standard for bio-oil, with SR having a particularly high calorific value, suggesting its high potential as an energy source. SR compares favorably with other listed materials such as rubber scraps and rapeseed oil. The lower density and viscosity of SS are advantageous for transport and atomization, whereas the higher calorific value of SR suggests that it can provide more energy per unit mass, although its higher viscosity may require modifications to fuel systems for optimal use. Both SS and SR have high flash points, which improve their safety profiles during storage and handling. SR pyrolysis oil is characterized by its high calorific value, suggesting that it is an excellent candidate for energy production, exceeding many bio-oil standards and comparable materials. The key to their application is to balance these characteristics with the requirements of the intended fuel systems and examine the economic feasibility of upgrading them to meet these requirements.

4. Conclusions

This study on the production of pyrolysis oil from Sacha Inchi waste provided valuable insights into the potential of utilizing Sacha Inchi residues (SR) and shells (SS) as raw materials for biofuel production through pyrolysis. Ultimate analysis of the waste materials revealed high carbon and hydrogen contents, indicating their suitability for conversion into carbon-rich materials, such as pyrolysis oil or biochar. Statistical analysis using ANOVA confirmed that the temperature was the most influential parameter affecting the production yield of pyrolysis oil. The results showed that higher temperatures, especially in the range of 400–450 °C, resulted in higher oil yields for both SR and SS. The optimal conditions for maximizing oil production were identified, with temperature playing a crucial role in increasing pyrolysis efficiency. The ultimate analysis of the pyrolysis oils further supported these results, showing that the carbon content increased at higher temperatures, indicating a more carbon-rich composition in the resulting oil. This research contributes to the further development of renewable energy technologies and highlights the potential for resource-efficient and sustainable use of agricultural waste streams for biofuel production. Further research and optimization of the pyrolysis conditions could lead to improved biofuel production from Sacha Inchi waste, contributing to the transition to a more sustainable energy future. However, scaling up the process might introduce challenges not observed in the laboratory, such as feedstock handling and heat transfer inefficiencies, which could affect the yield and quality of the pyrolysis products. This study suggests the use of catalysts in pyrolysis. Catalysts can potentially improve the yield and quality of pyrolysis oil, making the process more efficient, and the products more suitable for specific applications.

Data availability statement

Has data associated with your study been deposited into a publicly available repository?

- No.

Why ?

- Data included in article/supp. material/referenced in article.

CRediT authorship contribution statement

Chaiyan Chaiya: Writing – review & editing, Conceptualization. **Lerdluck Kaewvimol:** Writing – review & editing, Writing –

Table 6
Comparing the fuel properties.

Liquid fuel	Fuel Properties				
	Density @ 20 °C (g/ml)	Viscosity @ 40 °C (cP)	Calorific value (MJ/kg)	Flash Point (°C)	References
Bio-oil standard	1.10–1.30	<150	>15	>45	[24]
Rubber Residue	–	23.18	37.76	87	[25]
Rubber Shell	–	2.07	22.11	70	[25]
Rape seed	–	36.00	37.90	75	[26]
Soybean	–	72.38	33.60	63	[23]
Laurus nobilis L	–	61.00	31.04	65	[27]
OPMF	1.05	2.55	23.00	–	[19]
PE	0.82	1.84	46.67	<10	[28]
SS	1.04	2.05	31.53	122	This work
SR	1.25	4.88	38.43	105	This work

original draft, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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