Extraction of Vegetable Oil from Dacryodes Edulis (African Pear Leaves)

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Abstract

This study was used to investigates the extraction of vegetable oil from African pear leaves (Dacryodes Edulis) using petroleum ether as a solvent. The extraction was conducted maintaining the following controls: temperatures (45 ºC - 60 ºC), times of extraction (20min - 60min), particle sizes (optimal at 1.8 mm), and solvent volumes (300 ml). Physicochemical properties of the oil were analyzed, and oil yield predictions were made using power and kinetic models. Physicochemical analysis classified the oil as a non-drying oil with applications in diverse industries. Optimal conditions for maximum yield were determined, considering factors such as particle size, temperature, extraction time, and solvent volume. Extraction kinetics revealed that both power and first-order kinetic models effectively predicted oil recovery, with the power model exhibiting a slightly better performance. Contributions to knowledge include insights into the extraction of oil from African pear leaves, emphasizing the suitability of petroleum ether as a cost-effective solvent. Recommendations highlight the potential of locally produced pear leaf oil to meet Nigeria's demand for products, reducing dependence on imports. Furthermore, suggestions for equipment upgrades, consistent power supply, and enhanced water availability aim to improve research efficiency. Future research is encouraged to explore the intrinsic behavior of African pear leaf oil for comprehensive characterization and classification, advancing its potential applications.

Keywords*: Oil extraction, petroleum ether, power Log and kinetic models.*

Introduction

Plants contain valuable liquids with applications in medicine and food. Many of these liquids are refined to serve as raw materials for various domestic and industrial products. While most plants offer high nutritional value, the seeds or nuts, often discarded as waste after consuming the edible parts, surprisingly have a high oil content. This oil can be effectively utilized either industrially or domestically as raw materials for producing beauty products or for food processing (Yusuf, 2018). The use of plant oil, commonly referred to as vegetable oil, has been gaining significant attention. From a chemical perspective, vegetable oil is a compound with triglycerides of varying chain lengths, categorized as saturated or unsaturated. Saturated triglycerides consist of single bond compounds of carbon and hydrogen atoms, while unsaturated triglycerides are compounds with double bonds of carbon and hydrogen atoms (Nde and Foncha, 2020).

Vegetable oil is broadly categorized as either edible or non-edible. Edible oils are predominantly employed in food preparation and the manufacturing of pharmaceutical products. On the other hand, non-edible oils are commonly used as raw materials for biodiesel production (Khan et al., 2019), as well as in the manufacturing of soap, perfumes, cosmetics, antioxidants and bioactive compounds (Cortés et al., 2017). Vegetable oils intended for human consumption are extracted from non-harmful sources such as soybean, sunflower, rapeseed, canola, cottonseed, avocado seed, peanut, coconut, shea butter, and palm kernel seed, among other plant seeds (Iddrisu et al., 2019).while non-edible oil from Jatropha curcas L., Pimenta racemosa, Lavender, Calotropis procera, Sterculia apetala, Rhus typhina L. are used to produce biodiesel, perfumes, cosmetics, bio-lubricant and antioxidant among others (Budhwani et al., 2019). Seed oil from edible plants has equally been used by some researchers to produce biodiesel and other non-edible products (Okewale et al., 2020).

This study is driven by the imperative to minimize waste by effectively utilizing abundant and underutilized local raw materials prevalent in many local communities. Seeds from plants such as the African pear leaf are often discarded as waste in the environment. Yet, these leaves may contain essential oils that could be extracted. These oils hold significant value for both domestic and industrial applications. Numerous studies have highlighted that the percentage of oil extracted from plants is influenced by various variables (Agu et al., 2020). Hence, this research delves into the extraction of valuable oil from African pear leaves using the Soxhlet extraction method. The investigation encompasses various extraction temperatures, times, particle sizes, and feed/solvent ratios. Optimizing these parameters is crucial for maximizing the yield of African pear leaf oil, considering both the kinetics and thermodynamics of the extraction process.

Materials and Methods

The experiments were conducted at the Chemical Engineering Laboratory in Rivers State University, Port Harcourt Nigeria.

Materials

The materials used in the experiment include pear leaf, petroleum ether (solvent) with boiling point 45 - 62 ^{o}C.

Volumetric flasks, Soxhlet extractor, steam distillation apparatus, heating mantle, water bath, G-clamp, flasks, beakers, pipette, burette, sample bottle, specific gravity bottle, weighing balance, grinder, Gas chromatography Mass Spectroscopy (GC-MS) detector, pH meter thermometer and stop watch, Scientific Calculator and sieve merge.

Methods

The methods followed were based on Shreves' work (2012). Pear leaf were collected from Agricultural farm in Emu Town, Edo State and transported to the Department of Chemical/Petrochemical Engineering Laboratory, Nkpolu-Oroworukwo Port Harcourt for processing. The sample were weighed, washed, and sundried for 5 weeks. Thereafter, the leaves were ground to powdered form and sieved to particle sizes of 0.8 mm, 1 mm, 1.8 mm, 2 mm and 2.75 mm.

The oil extraction was done using a Soxhlet extractor with petroleum ether as the solvent. The samples were divided to explore the impact of temperature, particle size, extraction time, and solvent volume. Additionally, the pear leaf oil sample was analysed to determine Saponification Value, Acid Value, Iodine Value, Peroxide Value, and Free Fatty Acid. The impact of temperature on pear leaf oil yield was investigated using particle sizes of 0.8 mm, 1 mm, 1.8 mm, 2 mm, and 2.75 mm. Each sample, weighing 50 g, was subjected to extraction in a 500 ml round bottom flask with 300 ml of petroleum ether solvent. The extraction temperatures varied from 45 ºC to 60 ºC.

For each trial, one sample was placed in the thimble of the extractor, and 300 ml of petroleum ether was added to a 500 ml round bottom flask. Heat, set at 45 ºC, was applied using a mantle, and extraction ceased after 20 minutes. The resulting oil-solvent mixture underwent distillation at a temperature range of 45 ºC to 62 ºC. The lower boiling point of petroleum ether allowed it to distil out, leaving only the oil in the flask. The collected oil was weighed to determine the yield.

This process was repeated for the remaining four samples, maintaining the extraction temperature at 45 ºC but varying extraction times to 30, 40, 50, and 60 minutes. Distillation was performed after each extraction to recover the oil, and the yield was calculated for each set of extraction conditions.

Calculation of Oil Yield

The oil yield for each experimental condition was calculated using the formula.

$$Yield\ (\%) = \frac{weight\ of\ \ pure\ oil\ extracted\ \left(g\right)}{weight\ of\ \ particle\ \left(g\right)} \qquad (2.1)$$

Characterization of Pear Leaf Oil

The properties of the extracted oil were determined using standard methods described in literature or by the Association of Official Analytical Chemists (AOAC, 2012).

Determination of Saponification Value

The analysis was conducted following the method outlined by the Association of Official Analytical Chemists (AOAC, 2012). In a 250ml conical flask, 4ml of the oil sample was weighed, and 50ml of alcoholic-potassium hydroxide solution was added. The flask with its contents was then heated on a boiling water bath for 30 minutes, with intermittent shaking. To the solution, 1ml of phenolphthalein indicator was added, and titration was performed while hot against hydrochloric acid. A blank titration, containing all the reagents except the sample, was also carried out.

The saponification value (SV) was calculated using the given expression.

$$.SV = \frac{\left(B-S\right)\times N\times M}{w_o} \qquad (2.2)$$

Where,

B = blank titre value
S = sample titre value
N = normality of KOH (0.5 M)
M = molar mass of KOH (56.1)
w_o = weight of oil sample.

Determination of Iodine Value

The Iodine Value was determined following the AOAC method (2012). Approximately 0.35 ml of the sample was accurately weighed into a dry 250 ml conical flask. To this, 20 ml of carbon tetrachloride (CCl4) was added from a dry cylinder, and the flask was shaken to dissolve the oil. A 25 ml aliquot of the solution was pipetted into the flask in a fume cupboard and stoppered with cotton wool moistened with potassium iodide (KI) solution. The flask was left to stand for 30 minutes in the dark.

A blank titration was prepared, including all the reagents except the sample. The liberated iodide was back-titrated with 0.1 N Sodium thiosulphate, using starch solution as an indicator. The blue-black coloration turned colourless, and the titre value was recorded. This blank titration was also conducted.

The Iodine Value (IV) was calculated using the provided equation.

$$IV = \frac{\left(B-S\right)\times N\times 12.69}{w_o} \qquad (2.3)$$

Where,

B = blank titre value
S = sample titre value
N = normality of sodium thiosulphate
wo = weight of oil sample.

Acid Value

The Acid Value (AV) was calculated using the method described by Warra et al., (2012). Thus, 100 ml of neutral ethyl alcohol was heated with 10 g of the oil sample in 250 ml beaker until the mixture boils. The mixture is then titrated with 0.1 M KOH solution using phenolphthalein as indicator. The content was constantly shaken until the colour changed to pink. The AV is then calculated using the expression:

$$AV = \frac{TV \times N \times M}{w_o} \tag{2.4}$$

Where,
TV = titre value
N = normality of KOH (0.1 M)
M = molar mass of KOH (56.1)
wo = weight of oil sample.

2.5.4 Free Fatty Acid

The free fatty acid was determined according to (AOAC, 2012), This was calculated from the relationship between it and the acid value. The mathematical relation is expressed as:

Free fatty acid = Acid value × 0.503 (2.5)

Determination of Peroxide Value

The analysis, conducted following the method of the Association of Official Analytical Chemists (AOAC, 2012), was carried out in the dark. To begin, 5 g of the oil sample was weighed into a clean, dry boiling tube. Subsequently, 30 ml of a solvent mixture (12 ml acetic acid + 18 ml chloroform) was added to the tube, and the mixture was boiled for 60 seconds. The contents were then poured into a titration flask containing 1 ml of 2% potassium iodide and 30 ml of water.

The resulting solution was titrated against 0.01 N Sodium thiosulphate using 1 ml of 1% starch indicator. The endpoint was indicated by a milky color. A blank titration, excluding the sample, was also performed.

The Peroxide Value (PV) was calculated using the provided equation.

$$Peroxide\ Value\ (PV) = \frac{(S - B) \times N \times (1000)}{w_o} \tag{2.6}$$

Where,
B = blank titre value
S = sample titre value
N = normality of sodium thiosulphate
wo = weight of oil sample

Refractive Index

The refractive index was determined using Abbe Refractometer.

Specific Gravity

The specific gravity was determined according to method described in AOAC (2012). A density bottle was washed with detergent, water and petroleum ether. 100 ml of oil, the sample, and water sample were weighed via the density bottle to determine the respective weight. After recording of the weights, the specific gravity of the oil was then obtained using the expression;

$$Specific\ \ gravity = \frac{Weight\ \ of\ \ Oil}{Weight\ \ of\ \ equal\ Volume\ of\ \ water} \tag{2.7}$$

Colour
The colour was determined by physical observation.

Kinetics and Thermodynamics of Oil Extraction
Various kinetic models have been proposed for the study of oil extraction from plants. In this study, the power model and first order kinetic model were used to study the extraction of pear leaf oil. Also, the thermodynamics of the extraction process was evaluated using established models.

Power Model
The power model that was used in this study has been applied by some researchers in vegetable oil extraction kinetics (Umamaheshwari and Reddy, 2016). This is expressed as:

$$\frac{dY}{dt} = kY^n \tag{2.8}$$

Where,
Rate of oil yield (%/min)
Percentage of oil yield (%)
Extraction time (min)
Extraction rate constant (min-1)
Power index

The rate constant and power index can be determined by taking the logarithm of both sides as follows.

$$\ln\frac{dY}{dt} = \ln k + n\ln Y \tag{2.9}$$

A plot $\ln\frac{dY}{dt}$ against $\ln Y$ gives a slope equivalent to and intercept as k

Now, equation (2.8) can be integrated to predict the yield of oil. After integration, the determined values of the power index and extraction rate constant are substituted into the resulting equation for prediction of oil yield. That is:

$$\int\frac{dY}{Y^n} = k\int dt$$

$$\frac{Y^{1-n}}{1-n} = kt + C \tag{2.10}$$

where C is integration constant.
when t = 0, Y = 0. Then, it implies that C = 0. Therefore, equation (2.10) becomes:

$$\frac{Y^{1-n}}{1-n} = kt \tag{2.11}$$

Or $$Y^{1-n} = (1-n)kt \tag{2.12}$$

Multiplying the powers of both sides of equation (2.12) by $\frac{1}{1-n}$ gives

$$Y = \left[(1-n)kt\right]^{\frac{1}{1-n}} \tag{2.13}$$

Equation (2.13) can be simplified to as:

$$Y = \beta t^{m} \tag{2.14}$$

where: $\beta = (k - nk)^{m}$ and $m = \frac{1}{1-n}$

In this study, equation (2.14) is used to predict the amount of oil recovered with time. β is the characteristic constant incorporating the active coefficients, while the power index, m, is the diffusion exponent, which indicates the transport mechanism of oil, and it is less than 1 (n <1) in most oil extraction processes.

First Order Kinetic Model

The first order kinetic rate model for leaching process was applied in the work of Jabar et al., (2015) for the extraction *Thevetia peruviana* seeds, and this is stated as follows.

$$\frac{dW_t}{dt} = K\frac{A}{V}(W_e - W_t) \tag{2.15}$$

Where,

Mass of extracted oil at equilibrium (g)
Mass of extracted oil at time t (g)
mass transfer coefficient (cm/min)
A = Area of solid-liquid interface (cm2)
Volume of oil (cm3)
Extraction time (min)

Equation (2.15) can be expressed as:

$$\frac{dW_t}{dt} = K_a(W_e - W_t) \tag{2.16}$$

Where,

K_a = Volumetric mass transfer coefficient (min-1)

Assuming that equilibrium was attained within the period of this experiment, then, equation (2.16) is reduced to:

$$\frac{dW}{dt} = K_a W \tag{2.17}$$

Integration of equation (2.17) and simplification gives;

$$\ln W = K_a t + C \tag{2.18}$$

where C is the constant of integration, which accounts for the initial yield of oil
Expressing equation (2.18) in terms of yield gives;

$$\ln Y = K_a t + C \tag{2.19}$$

A plot of against t gives a slope equivalent to K_a and C as intercept.
To predict the amount of oil yield with time, the exponential of both side of equation (2.19) is taken to give;

$$Y_t = e^{K_a t + C} \tag{2.20}$$

RESULTS AND DISCUSSION

Physicochemical Properties of Pear Leaf Oil

The physicochemical properties of the extracted pear leaf oil are presented in Table 3.1, while the composition of the free fatty acid is presented in Table 3.2.

Table 3.1: Physicochemical Properties of Pear Leaf Oil

Parameter (unit)	Value
Saponification Value (mg KOH/g)	159.27
Iodine value (mg/100 g)	42.34
Acid value (mg KOH/g)	11.71
Free Fatty Acid (mg KOH/g)	4.15
Peroxide value (mg/g)	3.29
Refractive index (-)	1.46
Specific Gravity (-)	0.96
Colour	Light Yellow

The analysis of pear leaf oil's physicochemical properties provides valuable insights into its composition and potential utility. With a saponification value of 159.27 mg KOH/g, the oil may have some limitations for soap making compared to other oils. However, its iodine value falls within the typical range for plant oils, indicating versatility for various applications. The acid value of 11.71 mg KOH/g, although slightly higher than some plant oils, remains within acceptable limits. The free fatty acid value of 4.15 mg KOH/g aligns with recognized standards, suggesting a low risk of enzymatic hydrolysis. Notably, the peroxide value of 3.29 mg/g indicates significant oxidative stability, positioning pear leaf oil as a promising candidate for diverse industrial applications.

In summary, the iodine value indicates that the pear leaf oil can be classified as a non-drying oil, signifying a low presence of unsaturated fatty acids. While the saponification value might not be optimal for soap production, the oil demonstrates suitability for applications in food processing, plasticizers, biodiesel production, skincare products, and bio-lubricants. The low acid value positions the oil as a favourable precursor for creating resins essential for anticorrosion coatings. Furthermore, the peroxide value of 3.29 mg/g underscores the high oxidative stability of the oil, making it well-suited for commercial purposes with reduced risks of rancidity or unpleasant odours. These findings highlight the diverse potential and value of pear leaf oil in various industrial applications.

Table 3.2: Free Fatty Acids of Pear Leaf Oil

Fatty acid	No of Carbon: Bond	Weight (%)
Palmitic	C16:0	10.29
Linoleic	C18:2	18.63
Linolenic		0.76
Palmitoleic	C16:1	0.73
Oleic	C18:1	58.67
Stearic	C18:0	9.72
Myristic	C14:0	0.44

The fatty acid content analysis carried out on the oil revealed the various compositions and percentage of fatty acids in the pear leaf oil.

Yield of Pear Leaf Oil at Different Extraction Times and Temperatures

The experimental investigation recorded the percentage yield of oil from pear leaf at different extraction times and temperatures, while maintaining a constant particle size of 0.8 mm, 1 mm, 1.8 mm, 2 mm, 2.5 mm, and a solvent volume of 300 ml petroleum ether.

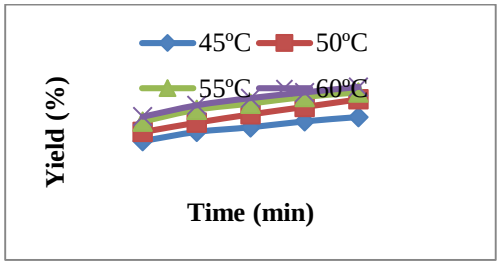

Figure 3.1: Oil Yield versus Extraction Time at Different Temperatures

Figure 3.1 illustrates the profiles of the percentage yield of pear leaf oil obtained through the solvent extraction method at extraction times ranging from 20 to 60 minutes and temperatures ranging from 45 ºC to 60 ºC. The plot indicates that the quantity of pear leaf oil, measured as the percentage of oil recovered after the extraction/distillation processes, increases with prolonged extraction time. Additionally, for a given extraction time, the oil yield rises with an increase in temperature. Specifically, the oil yield obtained between 20 minutes and 60 minutes at a temperature of 45 ºC ranged from 27.29% to 34.58%. Similarly, at temperatures of 50 ºC, 55 ºC, and 60 ºC, the oil yield ranged from 30.04% to 40.02%, 33.22% to 42.12%, and 34.72% to 43.77%, respectively, within the extraction time range of 20 minutes to 60 minutes. Consequently, the highest percentage of oil yield was achieved at a temperature of 60 ºC and an extraction time of 60 minutes.

The observations reveal that even within the chosen extraction time range, the percentage of oil yield continued to increase. Notably, between 50 minutes and 60 minutes of extraction time, especially at extraction temperatures of 55 ºC and 60 ºC, the difference in the amount of oil recovered was only about 3 – 4%. This suggests that if the extraction process were extended beyond 60 minutes, it could potentially lead to a higher yield of the oil. The findings indicate the sensitivity of the extraction process to both time and temperature, with the potential for further enhancement of oil yield with extended extraction durations. Though, some studies have reported insignificant yield of oil at about 60 minutes of extraction.

Yield of Pear Leaf Oil at Different Particle Sizes and Temperatures

The experimental study further explored the percentage oil yield from pear leaf at different particle sizes and temperatures, with the extraction time and solvent volume held constant at 60 minutes and 150 ml, respectively.

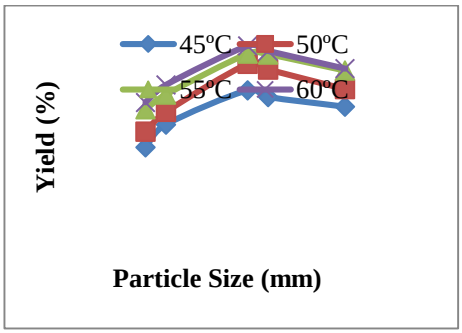

Figure 3.2: Oil Yield versus Particle Size at Different Temperatures

The study delved into the impact of particle size on pear leaf oil yield, encompassing sizes ranging from 0.8 to 2.75 mm. Different extraction temperatures were considered for each particle size, spanning from 45 ºC to 60 ºC at 5 ºC intervals. As illustrated in Figure 3.2, the pear leaf oil yield exhibited an upward trend with an increase in particle size, ranging from 0.8 to 1.8 mm. However, this trend reversed as the particle size further expanded to 2.75 mm, irrespective of the extraction temperature. Specifically, within the 0.8 to 1.8 mm particle size range, the oil yield increased from 22.74% to 34.58%, 25.99% to 40.02%, 30.64% to 42.13%, and 32.05% to 43.77% at temperatures of 45 ºC, 50 ºC, 55 ºC, and 60 ºC, respectively. Conversely, enlarging the particle size from 1.8 to 2.75 mm resulted in a decline in oil yield from 34.58% to 31.14%, 40.02% to 34.78%, 42.13% to 38.62%, and 43.77% to 39.03% at temperatures of 45 ºC, 50 ºC, 55 ºC, and 60 ºC, respectively.

This suggests that the maximum oil recovery from pear leaves was achieved with a particle size of 1.8 mm. Therefore, it is anticipated that at smaller particle sizes, the yield would be maximal due to the increased surface area. However, an unexpected result was observed as the lowest oil yield was recorded at the 0.8 mm particle size.

Yield of Pear Leaf Oil at Different Volume of Solvent and Temperatures

The experimental investigation of pear leaf oil yield involved varying solvent volumes and temperatures, while maintaining a constant extraction time of 60 minutes and particle size of 1.8 mm.

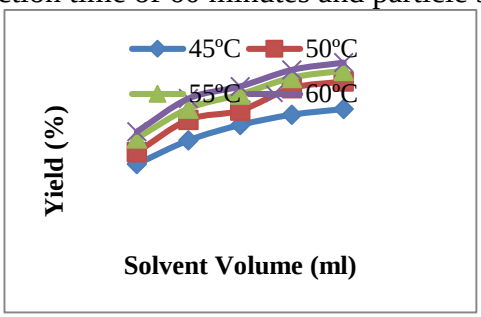

Figure 3.3: Oil Yield versus Solvent Volume at Different Temperatures

Figure 3.3 displays the variations in the percentage yield of pear leaf oil during solvent extraction, considering different solvent volumes (ranging from 150 to 350 ml) and temperatures (from 45 ºC to 60 ºC). The figure 3.3 illustrates an upward trend in the percentage of pear leaf oil with increasing solvent volume and extraction temperature. Specifically, elevating the solvent volume from 150 to 350 ml resulted in an increased oil yield at different temperatures, indicating a positive correlation between solvent volume, extraction temperature, and the yield of pear leaf oil.

Kinetic Analysis of Oil Extraction from Pear Leaf

The extraction of vegetable oil from plant seeds and leaves has been extensively explored through the application of mathematical expressions. To effectively utilize these models, it is essential to evaluate the constant coefficients using experimental data. In this study, the constant parameters in the mentioned kinetic models are determined based on the experimental data acquired, and the plots presented here facilitate this determination.

Evaluation of Power Model Constants

The power index (n) and the constant coefficient (k) were derived from the experimental data. Subsequently, the experimental results were fitted into equation (2.9) and plotted, as illustrated in Figure 3.4 at temperatures ranging from 45 to 60 ºC.

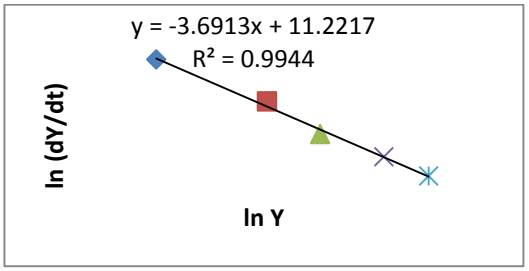

Figure 3.4: Plot for Evaluation of Power Index and Constant Coefficient at 45 ºC

Figure 3.4 displays the plot of the natural logarithm of the time rate of change in pear leaf oil yield against the natural logarithm of the yield at an extraction temperature of 45 ºC. Utilizing the power model, as simplified into equation (2.9), the index (n) and the constant coefficient (k) were determined by comparing the linear regression equation in Figure 3.4 with equation (2.9). Consequently, from the linear equation in Figure 4.4, it was found that \(n = -3.6913 \) and \(\ln k = 11.2217 \).
Hence, k = 74733.20 min^{-1}. By substituting into equation (2.14), the percentage yield of oil from the pear leaf at 45 ºC, can be expressed as: $Y = 14.6019t^{0.21}$.

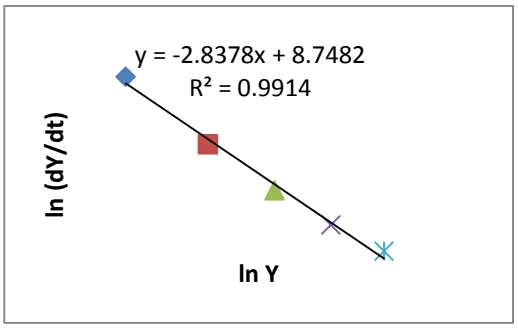

Figure 3.5: Plot for Evaluation of Power Index and Constant Coefficient at 50 ºC

In Figure 3.5, the plot depicts the natural logarithm of the time rate of change in pear leaf oil yield against the natural logarithm of the yield at an extraction temperature of 50 ºC. By applying the power model as simplified into equation (2.9), the index (n) and the constant coefficient (k) were determined by comparing the linear regression equation in Figure 3.5 with equation (2.9). Therefore, from the linear equation, n = -2.8378 and ln$k$ = 8.7482. Hence, k = 6299.49 min^{-1}. By substituting into equation (2.14), the percentage yield of oil from the pear leaf at 50 ºC, can be expressed as: $Y = 13.7937t^{0.26}$.

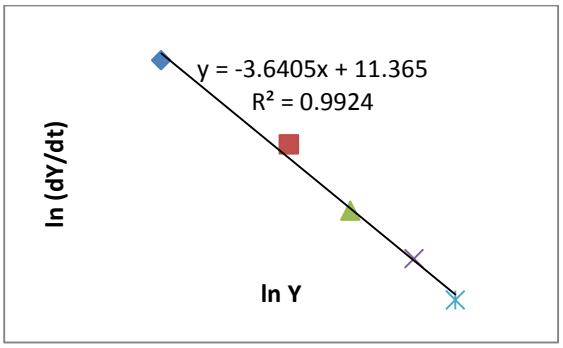

Figure 3.6: Plot for Evaluation of Power Index and Constant Coefficient at 55 ºC

In Figure 3.6, the graph depicts the natural logarithm of the time rate of change in pear leaf oil yield against the natural logarithm of yield at an extraction temperature of 55 ºC. Utilizing the power model simplified into equation (2.9), the obtained values for the index, n, and the constant coefficient, k, were derived by comparing the linear regression equation in Figure 4.6 with equation (2.9). Consequently, from the linear equation, the values were determined as n = -3.6405 and lnk = 11.3650, leading to k = 86249.60 min^{-1}. Through substitution into equation (2.14), the percentage yield of oil from the pear leaf at 55 ºC can be expressed as:.: $Y = 17.0809t^{0.22}$.

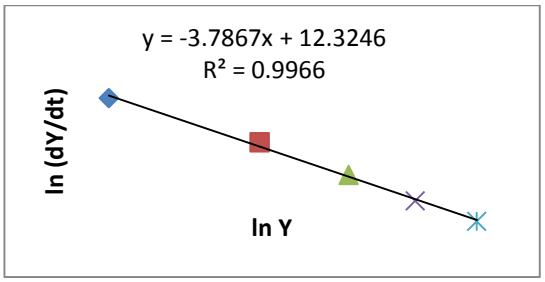

Figure 3.7: Plot for Evaluation of Power Index and Constant Coefficient at 60 ºC

In Figure 3.7, the graph illustrates the natural logarithm of the time rate of change in pear leaf oil yield against the natural logarithm of yield at an extraction temperature of 60 ºC. Employing the power model and simplifying it into equation (2.9), the index, n, and the constant coefficient, k, were determined by comparing the linear regression equation in Figure 3.7 with equation (2.9). As a result, from the linear equation, the values were found to be n = -3.7867 and lnk = 12.3245, leading to k = 225155 min^{-1}.

Evaluation of First Order Kinetic Constant

Similar to the power model, the constants in the first-order kinetics were established by fitting the experimental data into equation (2.19). The results were then plotted, as depicted in Figure 3.8, for different temperatures.

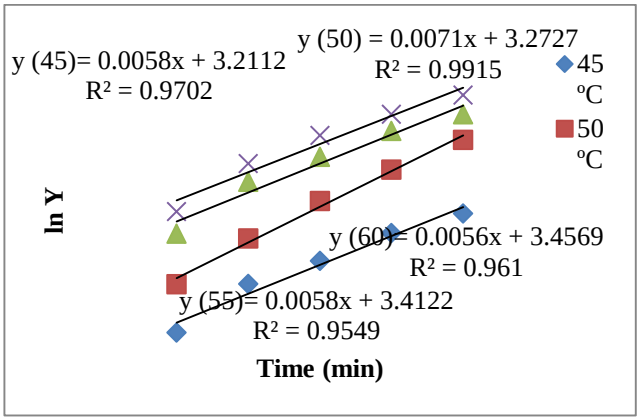

Figure 3.8: Plot for Evaluation of First Order Kinetic Rate Constant

In figure 3.8, the linear graphs depict the natural logarithm of pear leaf oil yield plotted against extraction time across temperatures ranging from 45 ºC to 60 ºC. The determination of the volumetric mass transfer coefficient, Ka, and the constant, C, was accomplished by comparing the linear equations in figure 3.8 with equation (2.19). Consequently, the obtained Ka values are 0.0058, 0.0071, 0.0058, and 0.0056 min^{-1} at temperatures of 45 ºC, 50 ºC, 55 ºC, and 60 ºC, respectively. Additionally, the corresponding C values are 3.2112, 3.2727, 3.4122, and 3.4569 at the respective temperatures.

Although the first-order kinetic model, which includes the equilibrium yield, has been applied in oil extraction, equilibrium was not achieved within the specified extraction variables. Therefore, the equilibrium yield has been neglected in this study. Some reports suggest that the kinetic constant in the first-order rate equation, when incorporated with equilibrium yield, is a function of extraction temperature, and the kinetic constant increases with temperature. By substituting Ka and C into equation (2.20), the percentage yield of oil from the pear leaf oil at various temperatures can be expressed and used for prediction.

Comparison of Kinetic Model Prediction of the Extracted Oil

The predictive accuracy of the first-order kinetic and power models was assessed at a temperature of 60 ºC, and the results were compared with the measured percentage of pear leaf oil yield, as illustrated in Figure 3.9.

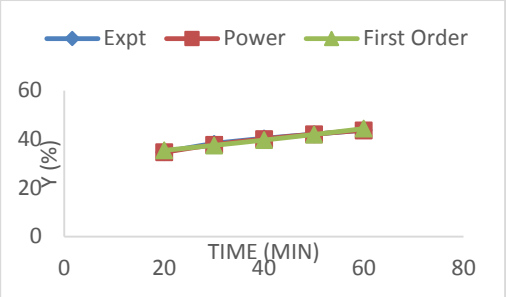

Figure 3.9: Comparison of the Degree of Model Predictions

The experimentally obtained percentage of pear leaf oil yield was compared with the values predicted by both the power and kinetic models, using the determined constants through subsequent substitutions. Figure 3.9 depicts the profiles of the percentage yield against extraction time, demonstrating the effectiveness of both models in predicting oil yield, with over 95% agreement with the experimental values. The deviation between the values predicted by the power model and the experiment ranged from 0.12% to 1.10%, while the deviation between the values predicted by the first-order kinetic model and the experiment ranged from 0.34% to 2.18%. This suggests a slight advantage of the power model over the first-order kinetic model.

Thermodynamic Analysis of Oil Extraction from Pear Leaf

Thermodynamics plays a pivotal role in comprehending heat transfer systems, and its relevance to oil extraction is notable due to the involved heating, leading to the exchange and transfer of heat from the solvent to the solid leaf particles. In the context of oil extraction, thermodynamics entails scrutinizing the process's state in terms of enthalpy and entropy.

The thermodynamic analysis initiates with the assessment of the equilibrium constant using equation (2.24), following the calculation of the constant K through equation (2.25). Subsequently, the thermodynamic parameters, specifically enthalpy and entropy, are determined based on the linear equation presented in Figure 3.10.

Conclusion

The investigation into the extraction of vegetable oil from pear leaves, employing petroleum ether as a solvent, covered a comprehensive exploration of factors such as temperatures, extraction times, particle sizes, and solvent volumes. Additionally, the study delved into the physicochemical properties of the oil, utilizing power and kinetic models for oil yield assessment. Thermodynamic properties were also scrutinized to gain insights into the heat dynamics, feasibility, and disorderliness of the extraction process.

Physicochemical analysis unveiled that the oil falls into the category of non-drying oils, as indicated by its iodine value. The saponification value suggested limitations for soap production but showcased potential applications across various industries. A low acid value highlighted the suitability of pear leaf oil as a precursor for synthesizing resins for anticorrosion coatings. Furthermore, the peroxide value attested to the oil's high oxidative stability, making it commercially viable without the risk of rancidity or offensive odours.

The analysis demonstrated that the percentage yield of pear leaf oil responds positively to increased extraction time, temperature, and solvent volume. However, specific particle sizes, particularly those below 1mm and above 2mm, were identified as potential factors leading to a decrease in oil yield. The optimal conditions for achieving maximum yield were pinpointed as a particle size of 1.8 mm, a temperature of 60 ^{o}C, an extraction time of 60 min, and a solvent volume of 400ml.

In terms of extraction kinetics, both the power and first-order kinetic models exhibited efficacy in predicting the percentage of recovered oil. Notably, the power model displayed a slightly superior performance. This comprehensive understanding of influential factors and optimal conditions contributes significantly to the efficient extraction of pear leaf oil, providing valuable insights for practical applications across various industries.

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