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DETERMINATION OF THE ENERGY POTENTIAL FROM SHEA BUTTER OIL AS SUITABLE ALTERNATIVE FUEL FOR INDUSTRIAL AND OTHER APPLICATION USES

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Abstract
This research aims to investigate and determine the energy potential of Shea butter oil as a viable alternative fuel for industrial applications. Shea butter oil, derived from the nuts of the shea tree (Vitellaria paradoxa), is a renewable resource with significant promise in the biofuel sector. The study aims to evaluate the physicochemical properties and calorific value of Shea butter as an alternative fuel for industrial and other application uses. The method includes obtaining Shea butter seeds from Sokoto Central Market, preparing the seeds for extraction, extracting the oil, and then determining the physicochemical properties. The results from Table 3.1 show the following: kinematic viscosity of 2.14, density of 868.78, cetane number of 50.25, cloud point of 9.34, specific gravity of 0.87, and flash point of 168. These results were compared with standard values of biodiesel, demonstrating that Shea butter has significant potential as an alternative fuel. However, Table 3.2 shows the calorific values of some properties of Shea butter, which include 74.52 kcal of fat, 0.42 kcal of protein, and 0.78 kcal of carbohydrate, leading to a total of 75.72 kcal. The high calorific value of Shea butter, primarily due to its fat content, makes it a promising alternative fuel for industrial and other application uses.

KEYWORDS: Shea Butter, Energy, Alternative, Industrial, Seed, Calorific

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1.0 Introduction

The primary sources of energy currently used and consumed worldwide are fossil fuels. Unfortunately, these resources are steadily depleting and are expected to run out in the near future. The rising consumption of fossil fuels, like petroleum, contributes to increased air pollution and global warming (Tulashie, 2018). Consequently, researchers have turned their attention to alternative and renewable energy sources, such as biodiesel and biodegradable fuels, which are more cost-effective and environmentally friendly (Kotoka et al., 2017).

Biodiesel has become a major focus in both developing and advanced countries, with the source of the fuel being a crucial consideration, especially regarding environmental impact. One of the most promising sources of biodiesel is shea butter derived from the shea nut tree, which grows naturally and abundantly in African countries such as Senegal, Nigeria, Cameroon, Ivory Coast, and Ghana. In its raw state, shea butter is relatively inexpensive, and the properties of the biodiesel produced depend on the physicochemical characteristics of the feedstock. Shea butter primarily consists of unsaponifiable materials and triglycerides, containing approximately 40-55% fat per kernel (Enweremodu et al., 2011).

Shea butter oil can be extracted from the kernels inside Shea fruits through a multi-step process that involves cracking the nuts, grinding them into a powder, and boiling the powder in water. The oil then rises to the surface and solidifies into what is known as shea butter. Despite the advantages of shea butter biodiesel, limited research has been conducted on its production and use as fuel (Tulashie et al., 2018).

This research aims to determine the energy potential of Shea butter as a suitable alternative fuel for domestic and industrial applications. The study will begin with the production of shea butter oil from shea seeds using the acid-alkaline transesterification process. Key physical and chemical properties, such as density, kinematic viscosity, flash point, cetane number, acid value, iodine value, and energy value, will be measured and compared with ASTM and EN standards for kerosene.

1.2 Problem Statement

The primary sources of energy currently used and consumed worldwide are fossil fuels. Unfortunately, these sources are gradually depleting and will eventually be exhausted. Additionally, the increased consumption of fossil fuels like petroleum contributes to air pollution and global warming. This situation has prompted researchers to explore alternative and renewable energy sources, such as biofuel, biodiesel, and biodegradable fuels, which are more cost-effective and environmentally friendly.

1.3 Aim and Objectives of the Study

Aim

The aim of this research was to determined the energy potential from shea butter oil as suitable alternative fuel for domestic and industrial use

Objectives

The objectives of this research work are as follows:
The objectives of this research work is to evaluate the physicochemical characteristic of Shea butter oil and compare with industrial fuel such as; this would be carry out based on the following:

a) Production of Shea butter oil from Shea butter seeds
b) To determine the physical properties of the Shea butter oil
c) To determine the chemical properties of Shea butter oil
d) To compare with the physicochemical properties of Biodiesel

2.0 Materials and Methods

2.1 Preparation of the Seed for Extraction

Shea butter (Butyrospernum parkii) seeds (nuts) were bought from Sokoto central market in Sokoto State, Nigeria. The seeds were then dehulled, cleaned, and sun-dried for a 24 hours before being placed in an oven for three hours at 50°C to minimize their moisture content as much as possible.

2.1.1 Oil Extraction

The prepared seeds were oven-dried at 70°C until a constant weight was achieved, then ground into smaller sizes. Extraction was performed using a Soxhlet apparatus with n-hexane as the solvent. After extraction, the mixture of solvent and extract was allowed to cool and then filtered to remove solid particles. The filtrate was concentrated under vacuum using a rotary evaporator (Akpan et al., 2005). The results were recorded, and the extracted oil was analyzed for its physical and chemical properties. All reagents used were of analytical grade.

2.1.2 Purification/ Refining

The oil was heated to 60°C, and commercially purchased activated carbon was added, resulting in the decolorization of the oil. The bleached oil was then mixed thoroughly with water and reheated to 60°C, stirred vigorously for 15 minutes, filtered, and cooled. The sludge collected on the filter paper was discarded. The purified oil was transferred into a

glass bottle and stored in a refrigerator until all analyses were completed (Munir *et al*., 2014).

2.2 Determination of Moisture

Moisture Content Determination: A 50 gram shear sample was weighed and dried in an oven at 80 °C. Every 2 hours, the sample was taken out of the oven and placed in a desiccator for 30 minutes to cool before being weighed again (Munir *et al*., 2014). The percentage moisture content in the seed was then calculated using the following formula:

$$\text{Moisture} = \frac{(W_1 - W_2)\%}{W_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where W_1 is the initial weight of sample before drying, W_2 is the final weight of sample after drying

2.3 Specific Gravity Determination

The specific gravity bottle was cleaned with acetone and ether, and then dried in an oven at 60°C. The weight of the empty bottle was recorded. Next, the bottle was filled with the oil sample and properly covered, and the weight was recorded using a weighing balance. The oil sample was then removed, and the bottle was thoroughly washed and filled with distilled water, after which its weight was recorded (Munir *et al*., 2014). Finally, the specific gravity was computed using the following relationship:

$$\text{Specific Gravity} = \frac{W_o - W}{W_1 - W} \quad \ldots\ldots\ldots\ldots\ldots\ldots 2$$

Where W = weight of empty bottle, W_o = weight of the bottle and oil content and W_1 = weight of bottle and water content

2.4 Determination of API gravity

The American Petroleum Institute (API) gravity was calculated based on the specific gravity of the shear butter using the following formula:

$$\text{API} = \frac{141.5}{Specific\ \ Gravity\ \ at\ 60^oF - 131.5} \ldots\ldots\ldots\ldots\ldots\ldots 3$$

2.5 Determination of Aniline point

The aniline point was determined according to ASTM (Reda 2014). Aniline oil was poured into a test tube, followed by the addition of the shea biodiesel sample. Initially, the two samples were immiscible, forming a double phase. The test tube was then placed in a rack and refrigerated. The lowest temperature at which the aniline oil and biodiesel mixed together was recorded as the aniline point.

2.6 Determination of Cetane index number

The cetane index measures the ignition quality of diesel fuel. A higher cetane index indicates easier starting of a standard diesel engine. The cetane index was determined using the Elizabeth *et al*, (2022) method, calculated with the following formula:

$$\text{Cetane Index} = \frac{Aniline\ \ Point\ x\ API\ Gravity}{10} \ldots\ldots\ldots\ldots\ldots\ldots 4$$

2.7 Determination of Flash Point

The flash (fire) point was determined by pouring the biodiesel sample into a glass Petri dish until the surface was covered. A mercury-in-glass thermometer was immersed in the sample so that its tip just touched the biodiesel. The thermometer was held in position using a retort stand and clamp. The sample was then placed on a laboratory heating mantle and gradually heated, with a light source applied at intervals. The lowest temperature at which the sample briefly ignited and then extinguished was recorded as the flash point, following the method described by Elizabeth et al. (2022).

2.8 Determination of Density

The density of the biodiesel was determined using; A 50ml pycnometer (density bottle) was thoroughly cleaned with detergent, water, and petroleum ether, then dried and weighed. The pycnometer was then filled with 50ml of synthesized biodiesel and weighed again. The weight of the biodiesel was calculated by subtracting the weight of the empty bottle from the combined weight of the filled bottle (Onwuka, 2005). Food analysis and instrumentation: theory and practice. Napthali prints.. The density was then determined by dividing the weight of the biodiesel by the known volume (50ml), using the following formula:

$$\text{Density} = \frac{Shea\ \ butter\ \ weig\,ht}{Shear\ \ butter\ \ volume} \quad 4$$

3.0 Results and Discussion

Table 3.1 Physicochemical properties of shea butter compared with the standard value of Biodiesel

Properties	Shea Butter Value	Standard Biodiesel
Kinematic viscosity (mm^2s^{-1}) at 40^0C	2.14	1.9 -6.0
Density (kgm^{-3}) at 25^0C	868.78	875 – 900
Cloud point ^0C	9.34	
Specific gravity	0.87	0.88
Cetane number	50.25	49 – 55
Flash point ^0C	168	130 min

Based on the comparison of the physicochemical properties of Shea butter with the standard values of biodiesel, Shea butter demonstrates significant potential as an alternative fuel for industrial use. Here is a detailed analysis of the results: from the analysis, the Viscosity (2.14 mm²/s), the Standard Biodiesel Range: 1.9–6.0 mm²/s, therefore when compared, it indicated that, 2.14 mm²/s of Shea butter's viscosity falls comfortably within the standard range for biodiesel, density (868.78 kg/m³) and Standard Biodiesel Range: 860–900 kg/m³. Shea butter's density is within the acceptable range for biodiesel, indicating similar energy content and combustion characteristics. This similarity suggests that shea butter can deliver comparable performance in terms of engine power and fuel efficiency. Flash Point (168°C), the minimum Standard for Biodiesel: 120°C. Therefore flash point of shea butter is significantly higher than the minimum standard, enhancing its safety for storage and handling. A higher flash point reduces the risk of accidental ignition, making shea butter a safer option for domestic fuel use. Cetane Number (50.25) and the Standard Biodiesel Range: 47–65. Cetane number also falls within the optimal range for biodiesel. A higher cetane number results in smoother engine operation, reduced engine knock, and improved combustion efficiency. Specific Gravity (0.89) and the standard Biodiesel value: Approximately 0.88. The specific gravity of shea butter is very close to that of standard biodiesel. And Cloud Point (9.34°C) and when compared with the Standard Biodiesel Range: -3°C to 12°C (depending on feedstock) Shea butter's cloud point is also within the range observed for biodiesel, indicating it is suitable for use in moderate climates. However, in colder climates, the higher cloud point may pose a challenge, as the fuel could start to solidify. This can be managed with additives or by blending shea butter with other lower cloud point fuels.

Table 3.2: Physicochemical properties of Shea butter

Sample	Fat (%)	Protein (%)	Carbohydrate (%)	Calorific value (kcal)
Shea Butter	828	10.52	19.43	75.72

Calculation of calorific value using table 2

1g of fat of Shea butter $\rightarrow$ 9 kcal

Therefore $\frac{828}{100}\ x\ 9kcal$ = 74.52kcal

For 828 % of fat produce 74.52kcal.

1g of protein of Shea butter → 4kcal

$\frac{10.52}{100}\ x\ 4kcal$ =0.42kcal

For 10.52 % of fat produce 0.42kcal.

1g of CHO of Shea butter → 4 kcal

$\frac{19.43}{100}\ x\ 4kcal$ =0.78kcal

These results was tabulated as shown in table 3

Table 3.3: Calorific value of some properties of Shea Butter

Sample	Fat (kcal)	Protein (kcal)	Carbohydrate (kcal)	Total calorific value (kcal)
Shea Butter	74.52	0.42	0.78	75.72

The results in Table 2 show that 74.52 kcal was calculated from 828% of fat, 0.42 kcal was obtained from 10.52% of protein, and 0.78 kcal was calculated from 19.52% of carbohydrate. Fat is the primary contributor to the calorific value of shea butter, indicating that fats have a high energy content per unit weight, making them efficient sources of energy. In the context of fuel, the high calorific value of fats means that Shea butter can generate a significant amount of energy when burned.

4.0 Conclusion

The physicochemical properties of Shea butter are well within the standard ranges for biodiesel, making it a promising alternative fuel for domestic use. Its viscosity, density, flash point, cetane number, and specific gravity align well with biodiesel standards, ensuring compatibility with existing diesel engines and fuel systems. The primary concern is its cloud point, which is manageable with proper formulation for colder environments. Overall, Shea butter offers a viable and safe alternative fuel option with efficient combustion characteristics.

However, the high calorific value of Shea butter, primarily due to its fat content, makes it a promising alternative fuel for industrial uses. Its energy efficiency, comparable to conventional fuels, and potential environmental benefits underscore its viability. However, practical considerations such as availability, cost, and sustainability of production are essential factors to consider in its widespread adoption as an alternative industrial fuel.

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