



Selected Physico-Calorific Properties of N-Hexane-Extracted Oil from *Albizia lebbek*'s Seed Sourced within the Campus of University of Benin, Nigeria

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Abstract

It has been observed that large proportion of the seeds produced annually by the trees of *Albizia lebbek* (L.) in many parts of Nigeria is mostly not utilised for value-added applications. This reality is unacceptable from the standpoint of sustainable management of renewable natural resources. Consequently, this research was carried out with the main aim of providing baseline information for the prospect of applying oil from *A. lebbek*'s seed in the production of biofuel. Oil used for the purpose of carrying out this research was obtained – using n-hexane as extracting solvent – from the seed of *A. lebbek* tree sourced within the campus of University of Benin, Benin City, Nigeria. The extracted oil was subjected to experimentations for the evaluation of some physical and calorific properties based on standard procedures as stated in the materials and method section. The results of the evaluations showed that the mean oil yield was $5.32 \pm 0.001\%$, its odour was unpleasant and colour was dark-brown, all these were obtained at room temperature of $25 \pm 2^\circ\text{C}$. Furthermore, it was observed that the oil's colour at temperature of 31°C and slightly above was yellowish-brown with its mean moisture content, obtained after heating to temperature of $105 \pm 2^\circ\text{C}$, being $5.15 \pm 0.002\%$. In addition, the oil's mean specific gravity and kinematic viscosity at $25 \pm 2^\circ\text{C}$ were 0.79 ± 0.0013 and $10.27 \pm 0.62\text{cSt}$ respectively while its mean net calorific value (NCV) was $31.74 \pm 0.014\text{kJkg}^{-1}$. The mean values obtained, particularly for NCV, can be said to be good enough for this oil to serve as a potential feedstock for biofuel production, irrespective of the seed's low oil bearing nature. However, it was recommended that more research that should be aimed at value-addition and utilisation of the seed and its potential products should be carried out.

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Introduction

The quest for more sources of vegetable oil is on owing to the fact that oil from plant parts are sourced for diverse purposes ranging from consumption by human and as feed component for animals to application as raw material in industrial/manufacturing sector (Oliveira and Da Silva, 2013; Adewuyi and Oderinde, 2014; Mohd-Setapar *et al.*, 2014; Knothe *et al.*, 2015). The usage of a number of these oils in the industrial/manufacturing sector will continue to increase in volume and intensity as this sector expands in size and activity including improvement in associated technology in developing countries. The implication of this expected possibility is that more research efforts should be geared towards identifying and optimizing the benefits from more sources of vegetable oil, particularly from

sustainable and dependable supply that do not have the potential of conflicting with usage as human food, to satisfy present and future demands.

An example of plant's part from which oil can be obtained is the seed. As stated earlier, oil from seed can be used for diverse purposes. This implies that seed oil from different plants has properties that distinguish and make them suitable for applications. Some of these properties, for different seed oils, might have been observed through unscientific/chance occurrence; nevertheless, modern scientific experimentations are necessary for verification of claims. This has necessitated some past researches that led to valuable results on different seed oils. For instance, some past studies were carried out on seed oil from *A. lebbek* (L.) tree, for it to be recommended

in applications, as this seed is presently underutilised in Nigeria. *Albizia* comprises about 150 species, mainly shrubs and trees (Prinsen, 1986). Specifically, *A. lebbek* is a medium to large tree, of multi-stemmed and may exhibit widespread canopy when grown in the open reaching 30 meters in diameter.

The height of *A. lebbek* can reach a maximum of 20 meters with rough bark and flat oblong pods (120–350mm X 30–60mm) that is stiff-papery when ripe producing 3–12 seeds per pod. Seed production is not a major problem since this tree can produce seeds annually (Larbi *et al.*, 1996). As with many legumes, there is no need to wait until pods are dry to harvest seed. Pods are mature when they have turned light yellow and should be harvested when the last patches of green are disappearing (Knothe *et al.*, 2015). Although, it may be difficult to extract oil through mechanical pressing from this plant's seed coupled with the observations that even the volume of oil obtained using solvent-extraction is also low when quantified, these do not negate the reality that there is still the need to conduct researches aimed at improving on this oil's application potential

The assertion that there is still the need for more research on this oil, despite the highlighted challenges, can be justified, among other reasons, on the basis that the oil may be useful for other applications since it is not known to be fit for human ingestion (Knothe *et al.*, 2015). In addition, the location of plant from which seeds are sourced is also known to influence its oil properties. Consequently, there is the possibility that oil from *A. lebbek*'s seed obtained from this and other parts of Nigeria may have physical and chemical properties that are different from those in literature. This research was thus carried out in order to contribute to information in this regard by evaluating some physical properties and net calorific value of oil obtained through liquid extraction from seed of *A. lebbek* trees sourced within the University of Benin campus, Benin City, Nigeria.

Materials and Methods

Sourcing of Seeds from *Albizia lebbek* trees

The matured pods containing the seeds from which oil was extracted and used for the research being reported were obtained through harvesting, in the months of January and February 2017, from properly identified tree species, known as *A. lebbek*, located within the campus of University of Benin, Benin City, on the southern part of Edo State, Nigeria. This area of Edo State lies between latitude 06°15'N–06°27'N and longitude 05°30'E–05°40'E. The topography is flat with gentle slope (Egbe *et al.*, 1989). The area has an annual rainfall of between 1,500 and 2,000mm with an average temperature of 25°C in the rainy season and 28°C in the dry season. It is part of a low lying plain

covered with porous sand that rises gently north-eastward, with soils derived from sand stones and shades and very recent deposits susceptible to leaching (Kalu and Anigbere, 2011).

Seed Removal from Pod, Drying and Storage

The harvested pods were manually opened in order to remove the enclosed seeds, carefully sorted with those considered spoilt or observed to have been attacked by insects removed and discarded. The seeds that appeared good were further completely separated from dirt and other impurities, thoroughly washed with clean water to remove other available debris and then air dried in line with Knothe *et al.* (2015) with regular movement of the seeds for adequate aeration for proper drying. This method was applied by Soetaredjo *et al.* (2008) and Erakhrumen, (2011) to reduce and stabilise the moisture content to the prevalent environmental condition. The seeds were stored, after each drying regime, in nylon lined jute bags at room temperatures of 25±2°C and prevented from contamination. Afterwards, they were daily air dried, as earlier done, with proper monitoring to prevent possible seed damage as a result of likely moisture fluctuations.

Seed-Oil Extraction

Firstly, the air dried seeds were subjected to oven drying at 105±2°C and severally weighed until constant weight was achieved. The oven-dried seeds were pulverised into smaller particles using a seed grinder. Pulverising the seeds was done to enhance the efficiency of extraction by the solvent (Seth *et al.*, 2007; Saxena *et al.*, 2011; Mohd-Setapar *et al.*, 2014). The pulverised seeds were weighed and divided into three equal parts. Each of the three equal parts was placed, one after the other, into Soxhlet extractor, and their oil completely extracted using n-hexane. Currently, n-hexane is extensively and preferably used for commodity vegetable oil extraction due to its extraction efficiency and ease of availability (Mohd-Setapar *et al.*, 2014). On completion of oil extraction, recovery from solvent was accomplished through the use of rotary vacuum evaporator.

Selected Physical Properties of the Extracted Oil

Yield of the extracted oil was quantified in line with slight modifications to the methods adopted by Mwithiga and Moriasi, (2007), Uquiche *et al.* (2008) and Erakhrumen, (2011) while moisture content of the extracted oil was determined through the method described in ASTM E203–16. Furthermore, specific gravity of the extracted oil was determined in line with similar methodology adopted in an experiment by Erakhrumen, (2011). The kinematic viscosity

(measure of the resistance of fluid to gravity flow), was determined for this oil with the use of Cannon–Fenske opaque (Reverse–Flow) viscometer in line with the method described in ASTM D445–17.

Net Calorific Value of the Extracted Oil

The net calorific value (NCV) was determined with the use of oxygen bomb calorimeter in line with ASTM D240–17. This was achieved by placing 1g of the oil into the crucible chamber of the calorimeter with the initial temperature recorded. Adequate flow of oxygen was ensured to allow for complete combustion process in the properly closed chamber under high pressure. The temperature was monitored consistently and recorded until the oil was completely burnt off. This experiment was replicated three times and the mean value recorded.

Results and Discussion

The results obtained from the evaluation of selected physical and NCV of the extracted oil are in Table 1. The quantity of oil obtained in terms of percentage ratio of weight of oil obtained to the total weight of dried and crushed seeds was $5.32 \pm 0.001\%$. It was observed that the odour of the seed oil was unpleasant while its colour at room temperature of $25 \pm 2^\circ\text{C}$ was dark–brown but turned yellowish–brown at higher temperature of 31°C and slightly above. The moisture content and specific gravity obtained for the extracted oil, at room temperature, were $5.15 \pm 0.001\%$ and 0.79 ± 0.0013 respectively. It was also observed that

viscosity at this room temperature was $10.27 \pm 0.62\text{cSt}$ while volatility was $47.74 \pm 0.896\%$. In addition, the mean NCV obtained for the extracted oil was $31.74 \pm 0.014\text{kJkg}^{-1}$. These are some of the physical and energy value properties – for a vegetable oil – to be acquainted with during its consideration as potential fuel in engines.

For instance, diesel engines, being types of engines just referred to earlier, can use several fuel types that include diesel fuel, straight vegetable oils, biodiesel – transesterified vegetable oil – and short chain alcohols. The seed of *A. lebbeck* tree is considered a low oil bearing type that yield quantity of oil as a low as $<1\%$ in some studies (e.g. Knothe *et al.*, 2015). Nevertheless, the mean value for oil yield obtained in this research was higher than that reported by Knothe *et al.* (2015) but fell within the same range as those obtained for *A. lebbeck*'s seed oil in studies such as Oderinde *et al.* (2008) and Adewuyi and Oderinde, (2014). Mean value of oil yield obtained in this study may appear slightly lower in comparison to those for some other seed oils in literature owing to multifaceted reasons. For instance, apart from seed's source and its physiological characteristics as factors, the type of solvent used in extraction may have influence on oil yield, as some of these solvents are capable of co–extracting different compounds that are insoluble in other solvents, from oil bearing seeds (Hron *et al.*, 1982; Ferriera–Dias *et al.*, 2003; Mohd–Setapar *et al.*, 2014).

Table 1: Results for the evaluated selected physical properties and net calorific value

Selected Properties		Mean values
Physical properties	*Oil yield	$5.32 \pm 0.001\%$
	*Odour	Unpleasant
	*Colour @ room temperature	Dark–brown
	Colour @ 31°C & slightly above	Yellowish–brown
	**Oil's Moisture Content	$5.15 \pm 0.002\%$
	*Oil's Specific Gravity	0.79 ± 0.0013
	*Oil's Kinematic Viscosity	$10.27 \pm 0.62\text{cSt}$
Calorific property	***Oil's Net Calorific Value	$31.74 \pm 0.014\text{kJkg}^{-1}$

*Values are means for three test samples obtained at room temperature of $25 \pm 2^\circ\text{C}$.

** Value is the mean for three test samples obtained at $105 \pm 2^\circ\text{C}$

***Mean for oil's net calorific value was obtained from three test samples

The mean value obtained for this oil's moisture content in this study falls between 5% and 13% that has been reported as the optimum range of moisture content in oilseed processing as also documented by Mohd–Setapar *et al.* (2014). Determining moisture content of this oil at a specified temperature (e.g. $105 \pm 2^\circ\text{C}$ for this study) is necessary owing to the fact

that when, for instance, it is subjected to combustion, the available moisture in the oil takes away part of its total or gross calorific value. This is because during combustion the available moisture is turned to steam which is lost with the flue gases. The energy to evaporate the water to steam is not recovered, so some of the theoretical energy content of the oil is lost this

way. The available total or gross energy minus the energy to evaporate moisture to steam is termed NCV (Erakhrumen, 2009) as reported here.

Furthermore, it was observed that the mean specific gravity value obtained for this oil was slightly lower than those for some other vegetable oils in literature (Noureddini *et al.*, 1992; Esteban *et al.*, 2012; Musa *et al.*, 2016). The reason for this may not be apparent from the results obtained here but it is not unlikely to be linked to the oil being solvent-extracted even as vegetable oils are accepted to possess large molecular sizes of triglycerides. It is, however, noteworthy that if vegetable oil such as this is to be used as fuel, for instance in internal combustion engines, a higher specific gravity value may not be an advantage as this may contribute to poor fuel atomisation due in part to the large size of droplets upon injection into the cylinder and also due to high-spray jet penetration (Esteban *et al.*, 2012). Optimal atomisation improves mixing and complete combustion, for example in diesel engines, which has great impact on emissions and efficiency (Selim, 2009).

The mean value obtained for kinematic viscosity, for the extracted oil at the room temperature in this study, was also lower when compared with kinematic viscosity values in literature for other vegetable oils at similar temperature range, either extracted mechanically or with solvent. This kind of result concerning low oil viscosity may be an advantage from certain perspectives. For instance, when viscosity of oil is too high it leads to poor fuel atomisation, higher Sauter mean diameter – the ratio of the mean volume to the mean surface of the fuel droplets – and lower spray speed than conventional diesel fuel (Machacon *et al.*, 2001; Lu *et al.*, 2005; Kegl, 2008; Suh *et al.*, 2008; Esteban *et al.*, 2012). Alternatively, it has been shown that viscous fuels have a higher lubricating effectiveness (Nwafor, 2003). Although, it has been observed that indirect injection engines are less affected than direct injection engines by viscosity differences (Syndi and Daniel, 2009; Misra and Murthy, 2010), nevertheless, when straight vegetable oils are to be used as fuel in unmodified diesel engines, the viscosity has to be lowered to allow appropriate atomisation or else incomplete combustion and carbonisation will eventually lead to engine damage (Esteban *et al.*, 2012).

In furthering the line of thought concerning the potentials of this solvent-extracted oil as biofuel, another important property to be considered is its calorific value. This property represents the quantity

of heat transferred to the combustion chamber indicating the available energy in such material being ignited and exposed to complete combustion. The NCV obtained for this straight vegetable oil was observed to be lower than most, if not all, the fossil fuels and this is in tandem with the trends in literature (Oliveira and Da Silva, 2013). Similarly, NCV for this oil was also slightly lower than those for some vegetable oil that were documented in some research outcomes such as Gravalos *et al.* (2008) and Wakil *et al.* (2012). Nevertheless, the mean NCV obtained for this solvent-extracted straight vegetable oil from seed of *A. lebbeck* tree in this study may not be considered too low if the published values for other vegetable oils are to be taken account of.

Additionally, it is important to state that there are some challenges associated with the direct use of straight vegetable oils as fuel, particularly in engines. Among these challenges are poor atomisation of fuel, incomplete combustion accompanied with heavy smoke emission, carbon deposition, sticking of oil rings, injector chocking mainly due to the high viscosity and low volatility (Wakil *et al.*, 2012). Therefore, one of the solutions that have been recommended for surmounting these challenges is the conversion of these oils to biodiesel through the biochemical method known as transesterification. It is however noteworthy that the values obtained for the evaluated selected properties for this oil, as presented in Table 1, show that it has good potential for being converted to biodiesel if need be and there is the possibility of the resulting biodiesel possessing the required properties for users' acceptance as also noted by Knothe *et al.* (2015).

Recommendations and Conclusion

The results obtained from this research have shown that the seed oil of *A. lebbeck* tree, although solvent-extracted, has some properties that may encourage its use in generating energy. This seed is low oil bearing type but this should not discourage oil extraction and application in product development. Instead, modern scientific intervention, particularly at seedling stage, should be employed in improving the volume of oil extractable from the seed. As stated earlier, the seeds of *A. lebbeck* tree, from which oil was extracted for this study, are currently not utilised for value-added products in this and most other parts of Nigeria. This reality should be an incentive for more researches intended for more value-addition and utilisation of the seed and its potential products.

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