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ENERGETIC CHARACTERIZATION OF BALANITES AEGYPTIACA FRUIT

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Abstract— **Balanites aegyptiaca is known as 'desert date', its spiny tree widely distributed in dry land areas of Africa and Asia. It's traditionally used in treatment of various ailments such as jaundice and intestinal worm infection. In this study it's used to determine the energy characterization of outer shell, internal shell, and kernel of balanites aegyptiaca. By using proximate tests and heating value (higher heating value and lower heating value). Infrared spectroscopy (IR) was used to determine the chemical composition. It was found that the moisture content of 7.20%, 7.18%, 5.70 and volatile matter of 74.04%, 76.35%, 87.53 and ash content of 2.74%, 3.17%, 2.99% and fixed carbon of 16.02%, 13.29%, 4.31% for outer shell, internal shell and kernel respectively. With higher heating value 18.40 MJ/kg, 18.10 MJ/kg, 14.93 MJ/kg and lower heating value 18.35 MJ/kg, 18.00 MJ/kg, 14.90 MJ/kg for outer shell, internal shell and kernel respectively.**

Keywords— **Balanites Aegyptaica, Proximate Tests, Heating value, Infrared spectroscopy**

I. INTRODUCTION

1.1 Biomass

Biomass can be converted into useful energy (heat or electricity) or energy carriers (charcoal, oil or gas) by both thermochemical and biochemical conversion technologies. Biochemical conversion technologies include fermentation for alcohol production and anaerobic digestion for production of methane-enriched gas. Four thermochemical biomass conversion technologies for energy purposes exist: pyrolysis, gasification, direct combustion, and liquefaction. The primary products from these conversion technologies may be in the form of energy carriers such as charcoal, oil or gas, or as heat. Various techniques exist for the utilization of these products. Secondary products may be derived through additional processing. In principle, most of the petroleum derived chemicals currently being used can be produced from biomass, but some will require rather circuitous synthesis routes. (Van Loo & Koppejan, 2008).

In general, the characteristics of the ideal energy crop are:
• high yield (maximum production of dry matter per hectare)
• low energy input to produce
• low cost
• composition with the least contaminants,
• low nutrient requirements.

Desired characteristics will also depend on local climate and soil conditions. Water consumption can be a major constraint in many areas of the world and makes the drought resistance of the crop an important factor. Other important characteristics are pest resistance and fertilizer requirements.

Biomass can be converted into three main types of products:
• electrical/heat energy,
• transport fuel,
• chemical feedstock. (Amani Abdelrahmi, 2013)

1.2 Types of Biomass:

1.2.1 Wood and agricultural products

Most biomass used today is home grown energy. Wood logs, chips, bark, and sawdust accounts for about 44 percent of biomass energy. But any organic matter can produce biomass energy. Other biomass sources can include agricultural waste products like fruit pits and corncobs. Wood and wood waste are used to generate electricity. Much of the electricity is used by the industries making the waste; it is not distributed by utilities; it is a process called cogeneration. Paper mills and saw mills use much of their waste products to generate steam and electricity for their use. However, since they use so much energy, they need to buy additional electricity from utilities.

1.2.2 Solid Waste

Burning trash turns waste into a usable form of energy. One ton (2,000 pounds) of garbage contains about as much heat energy as 500 pounds of coal. Garbage is not all biomass; perhaps half of its energy content comes from plastics, which are made from petroleum and natural gas. Power plants that burn garbage for energy are called waste-to-energy plants. These plants generate electricity much as coal-red plants do, except that combustible garbage—not coal—is the fuel used to re their boilers.

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1.2.3 Landfill Gas and Biogas

Bacteria and fungi are not picky eaters. They eat dead plants and animals, causing them to rot or decay. A fungus on a rotting log is converting cellulose to sugars to feed itself. Although this process is slowed in a landfill, a substance called methane gas is still produced as the waste decays. New regulations require landfills to collect methane gas for safety and environmental reasons. Methane gas is colorless and odorless, but it is not harmless. The gas can cause res or explosions if it seeps into nearby homes and is ignited. Landfi-lls can collect the methane gas, purify it, and use it as fuel. Methane can also be produced using energy from agricultural and human wastes. Biogas digesters are airtight containers or pits lined with steel or bricks. Waste put into the containers is fermented without oxygen to produce a methane-rich gas. This gas can be used to produce electricity, or for cooking and lighting (Center, 2017).

1.2.4 Ethanol

Ethanol is an alcohol fuel (ethyl alcohol) made by fermenting the sugars and starches found in plants and then distilling them. Any organic material containing cellulose, starch, or sugar can be made into ethanol. The majority of the ethanol produced in the United States comes from corn. New technologies are producing ethanol from cellulose in woody -bers from trees, grasses, and crop residues. Today nearly all of the gasoline sold in the U.S. contains around 10 percent ethanol and is known as E10. In 2011, the U.S. Environmental Protection Agency (EPA) approved the introduction of E15 (15 percent ethanol, 85 percent gasoline) for use in passenger vehicles from model year 2001 and newer. Fuel containing 85 percent ethanol and 15 percent gasoline (E85) qualifies as an alternative fuel. There are more than 10 million -flexible fuel vehicles (FFV) on the road that can run efficiently on E85 or E10. However, just fewer than 10 percent of these vehicles use E85 regularly. (Center, 2017).

1.3 Balanites Aegyptaica:

Balanites aegyptiaca; known as desert date in English or Heglig and laloub in Arabic. It is one of the most important tree species in Sudan (Mainly in Western Sudan) where it is known to have the widest natural range of distribution. According to El Amin (Amani Abdelrahmi, 2013) Balanites aegyptiaca belong to the family Balanitaceae and it is an armed tree 8-10 m high, often with a fluted bole (Figure1). Bark grey to dark brown with deep vertical fissures exposing the new yellow bark; spines straight, stout, rigid, up to 8 cm long, inflorescence supraxillary or subracemose; flowers yellow-green, about 1.3 cm long. Flowers November – April; fruits December to July. (Fadl, 2015).

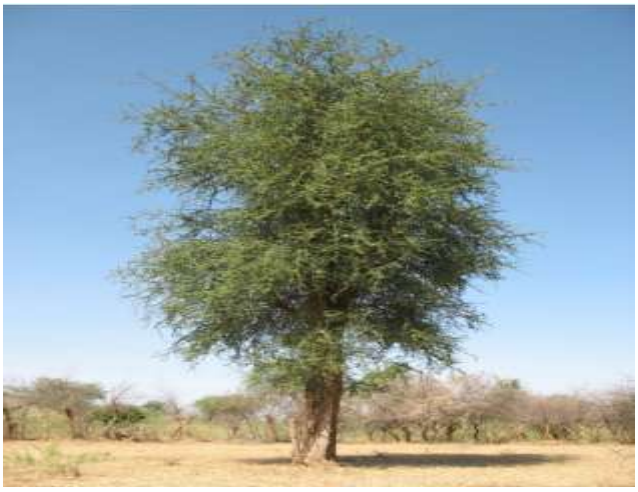

Fig. 1. Balanites aegyptiaca tree at El-Obeid town, Sudan (Fadl, 2015)

Fig. 2. Balanites aegyptiaca fruits

The fruits of B. aegyptiaca locally known as “Lalob” are an edible fruit. The fleshy pulp of the ripe and unripe fruit is eaten dried or fresh. In western and central Sudan the fruits are collected by women, children’s and sold in the local market to provide additional income for the family especially during the dry season after crop harvesting. B. aegyptiaca is one of the most important fodder trees in western Sudan which often have a higher crude protein, minerals content and higher digestible dry matter particularly during the dry season. (Fadl, 2015).

II. LITERATURE REVIEW

The fruits of B. aegyptiaca locally known as “Lalob” are an edible fruit. The fleshy pulp of the ripe and unripe fruit is eaten dried or fresh. In western and central Sudan the fruits are collected by women, children’s and sold in the local market to provide additional income for the family especially during the dry season after crop harvesting. B. aegyptiaca is one of the most important fodder trees in western Sudan which often have a higher crude protein, minerals content and higher

digestible dry matter particularly during the dry season (Anon, 2004). Lazim (2007) in his investigation on composition of some fodder trees in South Kordufan State reported that crude protein of B. aegyptiaca and Ziziphus spina- Christi could be adequate to meet the requirements of the ruminants in the late dry season. However, B. aegyptiaca leaves and twigs seemed to be useful as protein supply to poor grass range. The antibacterial effect of B. aegyptiaca was reported by Doughari et al. (2007). He reported that organic leaves extracts of B. aegyptiaca and Moringa oleifera can be used against Salmonella typhi which causes the typhoid fever. The antibacterial activity of the extracts on S. typhi was reasonably stable when treated at 4, 30, 60 and 100 C o for one hour. The tree- crashed fruit is used as a source for the bio diesel in USA (Mordechay et al., 2008). The wood is hard, durable, worked easily and made wooden spoons, pestles, mortars, handles, stools and combs. In Sudan the wood is used for different use such as furniture, charcoal making, fencing material, ornamental; shad for domestic livestock, insecticides, drugs, sand dune fixation, shelter belts and life fences. Young leaves and tender shoots are used as a vegetable, which is boiled, pounded, then fried or fat added to prepare it. Flowers are sucked to obtain nectar. In Burkina Faso, B. aegyptiaca contributed up to 38% of the dry-matter intake of goats in the dry season. The oil remains stable when heated and has a high smoking point, and therefore its free fatty acid content is low. Its scent and taste are acceptable. Wood gum mixed with maize meal porridge is used to treat chest pains. (Fadl, 2015).

The chemical composition of the root, stem bark, leaves, fruit pulp, seed kernel, and mesocarp of Balanites aegyptiaca has been studied by different scholars. A qualitative phytochemical analysis of the stem bark of Balanites aegyptiaca by Mutwali and Abdelgadir (2016) indicated the presence of alkaloids, tannins, triterpenoids, saponins and two biomolecules: amino Acids and carbohydrates. Balanitin 1, 2 and 3, alkaloids and diosgenin have been isolated from the root part of the East African Balanites aegyptiaca. Diosgenin is a steroidal sapogenin (5-spirostan-3- ol) compound which is very useful in pharmaceutical industries as a natural source of steroidal hormones (Zarroug et al., 1990 cited in Yadav and Panghal, 2010). The results of the study by Fregon and Shakak (2016) revealed that Balanites aegyptiaca seed contains oil, protein, fiber, carbohydrate and various minerals such as calcium, sodium, magnesium, phosphorus and potassium. The fatty acid profile of Balanites aegyptiaca seed oil also showed that it contains linoleic acid, palmitic acid, stearic acid and oleic acid. The oil of Balanites aegyptiaca also contains steroids such as saponins, sapogenins, diosgenins, which are used as raw material for industrial production of contraceptive pills, corticoids, anabolisants and other sexual hormones (Fregon and Shakak, 2016; Mutwali and Abdelgadir, 2016).

The fuel quality parameters such as the flash point and specific gravity of the Balanites aegyptiaca biodiesel are similar to those of D2 diesel. It's biodiesel is "readily biodegradable" compared with the D2 diesel, which is partially degradable. These suggest that Balanites aegyptiaca seed oil is a potential source of environmentally friendly biodiesel (Jauro and Adams, 2011). (Seifu, 2018).

Seeds Today most of the seeds go unused, but in certain areas they are gathered in quantity. After soaking and sun drying, they can be safely stored for months. Subsequently, the kernels are extracted. Roasted, these balanites nuts have an enticing aroma and are typically added to soups and to the various cereal products that are enjoyed in Senegal, Nigeria, Chad, Uganda, and Sudan. The Shuwa in northeastern Nigeria, for example, commonly eat them this way. And to some Shari and Chad peoples these seeds are so important they are the foundation of everyday life.

Seed oil the seed's kernel can contain up to 60 percent of almost tasteless oil. Sometimes called zachon or betu oil, it is highly prized especially in Sudan. The culinary properties are comparable to those of a quality vegetable oil. In a recent market survey, for instance, consumers rated it with cottonseed oil for flavor and cooking qualities.

Shells Every ton of whole fruit yields half a ton of woody shells. These shells are hard, dense, and highly combustible. They make good fuel as well as good charcoal and particleboard. (Academies, 2008).

III. MATERIAL AND METHOD

3.1 Material

Balanites aegyptiaca fruit was divided into three parts, which are: outer shell, internal shell and kernel/Nut and after drying each of them, the samples were grinded and sieved as in the figures (3, 4&5).

Fig. 3. Outer shell

Fig. 4. Internal shell

Fig. 5. Kernel/nut

Table (1): shows the mesh sizes used to sieve the samples

	Outer shell	Internal shell	Kernel/Nut
MESH NO	28	36	28
MESH SIZE	495 Micron	420 Micron	495 Micron

3.2 Chemical composition of the samples:

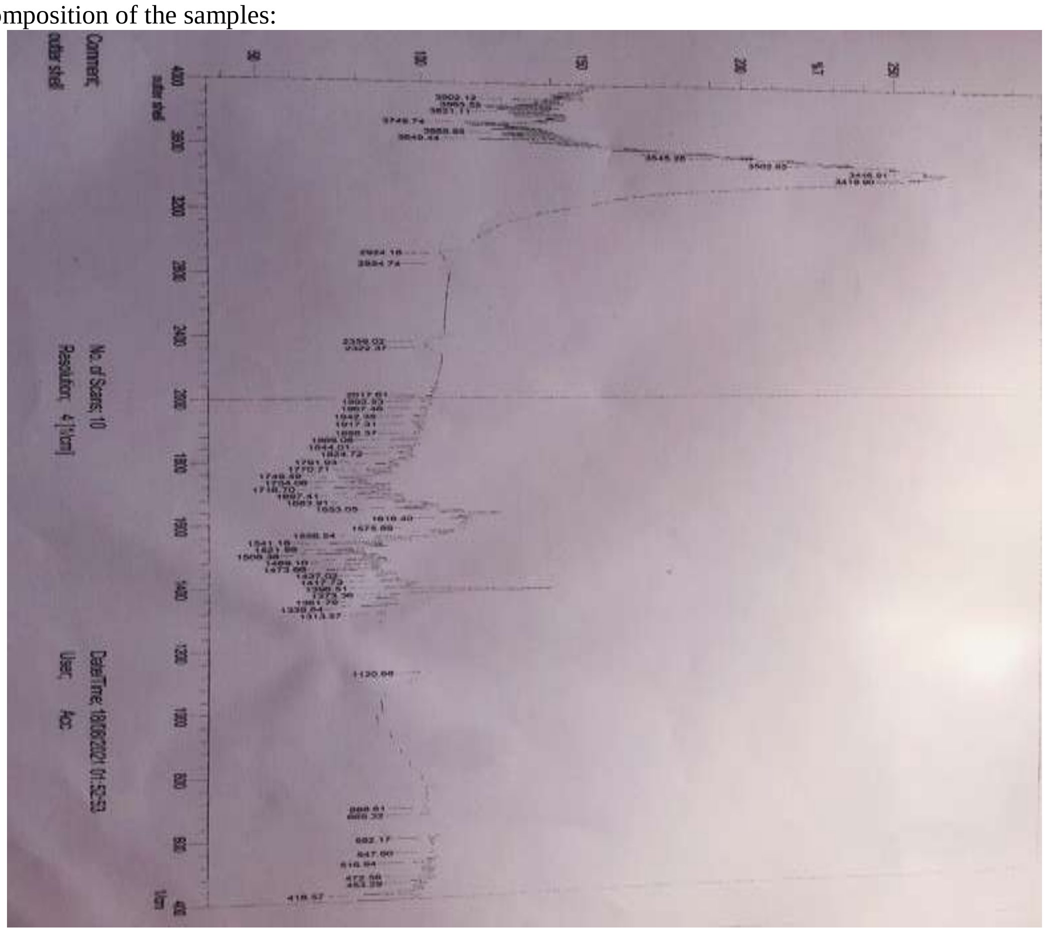

Fig. 6. Infrared spectroscopy (IR) for outer shell

Table (2): shows the chemical composition of outer shell according to figure (6)

Frequency (cm^{-1})	Functional group
3502.85	
3502.85	Single bond region including:
3446.91	N-H stretch
3419.90	O-H stretch
2924.18	C-H stretch
2854.74	
2359.02	Triple bond region:
2322.37	$C\equiv C$
2017.61	$C\equiv N$
1791.93	Double bond region:
1770.71	C=C
1749.49	C=O
1734.06	C=N
1716.70	
1697.41	
1683.91	
1653.05	
1616.40	
1396.51	Single bond region
1373.36	C-C
1361.79	C-O
1338.64	C-N
1313.57	
1120.68	
688.61	
669.32	

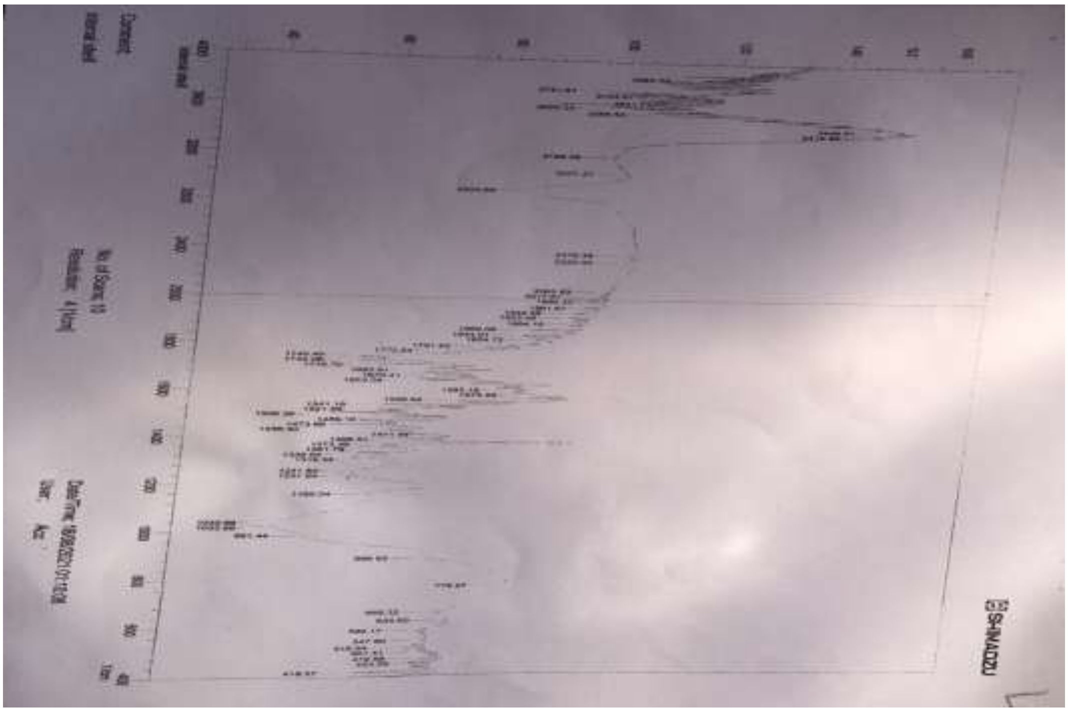

Figure (7): Infrared spectroscopy (IR) for internal shell

Table (3): shows the chemical composition of internal shell according to figure (7)

Frequency (cm^{-1})	Functional group
3446.91 3419.90 3190.90 3198.08 3057.27 2904.89	Single bond region including: N-H stretch O-H stretch C-H stretch
2376.38 2320.44 2017.61	Triple bond region: C≡C C≡N
1791.93 1772.64 1749.49 1734.06 1716.70 1683.91 1670.41 1653.05	Double bond region: C=C C=O C=N
1396.51 1373.36 1361.79 1338.64 1319.35 1251.84 1165.04 1033.88 991.44 896.63 779.27 669.32 634.60	Single bond region C-C C-O C-N

Fig. 8. Infrared spectroscopy for Kernel/Nut

Table (4): Shows the chemical composition of Kernel/Nut according to figure (8)

Frequency (cm^{-1})	Functional group
3462.34 3419.90 3010.98 2924.18 2854.74	Single bond region including: N-H stretch O-H stretch C-H stretch
2359.02 2198.92 2017.61	Triple bond region: C≡C C≡N
1791.93 1772.64 1747.57 1716.70 1697.41 1683.91 1653.05 1624.12	Double bond region: C=C C=O C=N

1396.51	Single bond region
1361.79	C-C
1338.64	C-O
1313.57	C-N
1288.49	
1120.68	
1039.67	
1039.67	
987.59	
864.14	
721.40	
688.61	
669.32	
634.60	

(Jestada Posom, 2020).

3.3 Proximate Tests

Proximate Testing includes testing of water content (Moisture Content), ash (Ash Content), volatile matter (Volatile Matter). This testing is conducted by heating or combusting the Biomass Powder in high temperature furnaces. Percentages of moisture contents, volatile matter and ash contents in all the parts were determined separately by following American Society of Testing Materials (ASTM) standards D3173- 87, D 3175-07 and D 3174-04, respectively and British standards (EN 14774-1). The fixed carbon percentage was determined by subtracting the sum of moisture contents, volatile matter and ash contents from 100. (Ashaq Ahmed, 2018).

3.3.1 Moisture Content Test

1 gram of sample (outer shell) was entered into the Moisture Analyzer Instruments at a temperature of 130 °C and at a time 5.40 min The Moisture content was determined and it was 7.205% of total weight.

1 gram of sample (Inner shell) was entered into the Moisture Analyzer instruments at a temperature of 130 °C and at a time 4.40 min The Moisture content was determined and it was 7.186% of total weight.

1 gram of sample (Kernel/Nut) was entered the Moisture Analyzer Instruments at a temperature of 130 °C and at a time 5.30 min. The Moisture content was determined and it was 5.169% of total weight.

3.3.2 Ash Content

Ash contents were calculated using the following Equation:

$$ASH\ CONTENTS\ (wt\%) = 100 - \frac{Wmd_0\_W}{WdS_0} * 100$$

(1)

Where:

Wmd_0 is the initial weight of the sample plus crucible

W is the weight of the sample and crucible after heating,

WdS_0 is the weight of the biomass sample.

3.3.3 Volatile Matter

Volatile matter is important property as it indicates the ease of combustibility of the biomass. High volatile matter contents in biomass indicate ease of processing and more liquid product during the pyrolysis process. Volatile matter contents present in the samples were calculated by following the two steps. In the first step weight loss in biomass sample were calculated using the following equation:

$$WEIGHT\ LOSS\ (wt\%) = \frac{Wmd_0\_W}{WS_0} * 100$$

(2)

Where:

Wmd_0 is the weight of the sample plus crucible.

W is the weight of the sample and crucible after heating.

WS_0 is the initial weight of the sample.

Then the volatile matters were calculated by the following equat,

$$VOLATILE\ MATTER\ (wt\%) = WEIGHT\ LOSS\ (wt\%) - MOISTURE\ CONTENTS\ (wt\%)$$

(3)

3.3.4 Fixed Carbon

Fixed carbon contents in the samples were calculated by subtracting the moisture contents, volatile matter and ash contents from 100, as in the following equation:

$$FIXED\ CARBON\ (wt\%) = 100 - (\mathrm{MOISTURE\ CONTENTS} + VOLATILE\ MATTER + ASH\ CONTENTS)$$

(4)

(Ashaq Ahmed, 2018)

3.4 Heating Value

Heating value, it is a measure of the amount of energy that can be released per unit mass, through an oxidation reaction. Is the characteristic probably better define the suitability of solid biomass as a fuel. (Gisela Montero, 2016)

Heating value is an expression of the energy content, or heat value, released when burnt in air.

Usually measured in terms of the energy content per unit mass MJ/kg for solids. The CV of a fuel can be expressed in two forms, higher heating value (HHV) and lower heating value (LHV). (Mckendry, 2002).

HHV & LHV can be calculated by the following equations:

$$HHV = 19.2880 - 0.2135 \times \frac{VM}{FC} + 0.0234 \times \frac{FC}{ASH} - 1.9584 \times \frac{ASH}{VM} \quad (5)$$

(zia-ud Din, 2015)

$$LHV = HHV - 2.443 \times MC \quad (6)$$

(Jestada Posom, 2020)

IV. RESULTS AND DISCUSSION

Proximate tests and heat values given in table 5 and 6 from the moisture content test we can notice that the moisture values for all the samples are < 10% and its means the samples are suitable for thermochemical conversion processes. Fixed carbon is used to estimate the amount of coal that will be generated from the sample of fuel material. Higher heating value (HHV) and lower heating value (LHV) are estimated according to the proximate tests. (Mckendry, 2002).

Table (5): proximate analysis for the balanites aegyptiaca:

Parameter / Sample	Moisture content %	Volatile matter %	Ash content %	Fixed carbon %
Outer shell	7.20	74.04	2.74	16.02
Internal shell	7.18	76.35	3.17	13.29
Kernel/Nut	5.70	87.53	2.99	4.31

Table (6): HHV and LHV according to proximate analysis:

sample	HHV (MJ/Kg)	LHV (MJ/Kg)
Outer shell	18.40	18.35
Internal shell	18.10	18.00
Kernel/Nut	14.92	14.90

V. CONCLUSION

Chemical composition of balanites aegyptiaca estimated by Infrared spectroscopy (IR) test. The result of proximate tastes showed in table (5). The HHV and LHV estimated according to the proximate analysis and the results were showed in table 6. So according to the previous results it's possible to convert the Balanites Aegyptaica fruit to the useful clean energy. This study recommend perform scanning electron microscope (SEM) to estimate the shapes and composition for the samples as well as Calculate the heating value according to the percentages of elements obtained from the (SEM) test and compare it with the heating value calculated in this study.

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