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# Egusi melon (*Citrullus lanatus*) crop – Malaysian new oil/energy source: Production, processing and prospects

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**Abstract**

Egusi melon (*Citrullus lanatus)*, a tropical crop mostly grown in parts of Africa, was introduced and grown in Malaysia to establish its adaptation and performance for oil and bio-energy. The crop was planted on a 200m$^2$ area planting plot on two seasons (Malaysia's dry and wet seasons). A total of 1127 fruits/200m$^2$ (or 5.635 fruits/m$^2$), produced 45.5kg/200m$^2$ (or 0.2275kg/m$^2$) seeds after processing during dry season. Harvest on wet season over same planting area, using same crop maintenance produced 448 fruits/200m$^2$ (or 2.24 fruits/m$^2$), with total seed mass of 5.49 kg/200m$^2$ (or 0.0275kg/m$^2$). Randomly selected 100 fruits after processing produced an average of 330.6 seeds/fruit, weighting 65.652g/fruit. Planting, monitoring and harvesting to obtain seeds from the fruits was presented. Seeds were sun and then oven dried in line with the ASAE S 352 standards to achieve moisture content of 7.11%, and were then ground for oil extraction. Crude oil from the seeds was extracted using sohxlet extraction method with hexane as solvent. Oil content from 800g of both seed kernel and whole seeds were 55.64% (444.96g) and 44.97% (358.84g), respectively. The fuel properties of its biodiesels show Cetane numbers of 52.54 and 53.06 and kinematic viscosities (@ 40$^0$C) of 3.00 and 2.53 mm$^2$/s for EDSOME and EWSOME respectively, with very low pour and cloud points for both. It was concluded to be good source of oil and can be used for biodiesel and biomass and recommended for planting in tropical countries, as it requires less rainfall for better yield.

**Keywords:** Egusi seed, oil, Cetane number, kinematic viscosity, cloud and pour point.
**Abbreviations**: ASAE_American Society of Agricultural Engineers, ASTM_American Standard of Testing Materials, EN_ European Standard, SD_Standard Deviation, EDSO_Egusi dehulled seed oil, EWSO_Egusi whole seed oil, EWSOME_Egusi whole seed oil methyl ester, EDSOME_Egusi dehulled see oil methyl ester.

## Introduction

Exploring new energy/oil crops is mandatory to checkmate the effect of fossil fuels on the environment. Many oil crops were discovered around the world, but the major mitigating factor is lack of adaptability of some of these crops in other parts of the world, which may be related to the climatic conditions in different geographical locations. The environmental effect of fossil fuels is an issue of major concern to researchers worldwide, which is linked to human activity, especially in the oil and gas industry (Pinto et al., 2005), thus, quest for newer renewable energy sources has become of paramount importance. Several oil crops have been identified in several parts of the world (Balat and Balat, 2008; Demirbas, 2009), however, some crops are environmental sensitive; and thus may not grow in some locations, or produce poorly due to factors such as rain, humidity and environmental temperature (Pinto et al., 2005; Demirbas, 2009). Among other oil crops commonly found in Africa are Jatropha, sesame, oil palm, sunflower, and rapeseed (Marvey, 2009). In West and East Africa, egusi melon seed has been a good source of oil, and is generally reported by many researchers to be grown largely in central Africa (Bande et al., 2012a) and in southern Sahelian zones and neighboring savannas (Jeffrey, 1980). It has also been proved to be a good source of bio-fuel (George et al., 2010), in addition to its values as a food source. The growth and utilization of this seed is not limited only for food and for medicinal purposes as reported by Oyolo (1982) and Eugene and Gloria (2002); in cosmetics (George *et al.*, 2010), but also as a biodiesel feedstock (Giwa et al. 2010). Egusi melon crop is a ground creepy crop and thus good for mixed farming system and its spreading nature covers the ground and as such suppresses weed growth on farm, thereby cutting down on the cost of its production (Bande, *et al.*, 2012 b). The crop was introduced in Malaysia on a fundamental research work to observe its adaptation and propagation for biodiesel and biomass. It was observed that every part of the crop; roots to the skin and flesh of the crop is a source of energy, in addition to high calorific value of its crude oil and biodiesel. The by-product from the seeds after oil extraction can be used as livestock feed, since it contains about 20% proteins (Eugene and Gloria, 2002). The biodiesel qualities of the oil from both seed kernels and the whole seed were tested and conform to ASTM and EN standards. Flash points, kinematic viscosities, acid values and Cetane numbers to mention a few, were in the range of both ASTM and EN standards. Figures 1, 2 and 3 shows the whole egusi fruit, cut fruit showing seed layout and washed seeds being dried in the sun.

**Table 1.** Fruits production by season (Dry and wet seasons).

| | Dry– season harvest | | Wet – season harvest | |
|---|---|---|---|---|
| | Fruit (200m$^2$) | Estimated fruits/ha | Fruit (200m$^2$) | Estimated fruits/ha |
| Fruits | 1,127 | 56,350 | 448 | 22,400 |
| Matured fruits | 702 | 35,100 | 344 | 17,200 |

**Table 2.** Fertilizers and pesticide consumables from planting to harvest of fruits.

| | Quantity (200m$^2$) | No. of app. | Quantity/ha |
|---|---|---|---|
| Fertilizer (NPK blue) | 0.5kg | 2 | 50kg |
| Fertilizer (NPK green) | 0.5kg | 2 | 50kg |
| Pesticide (Deltamethrin 2.8% w/w) | 40ml | 6 | 12 liters |

**Results**

***Planting to harvest***

Two seasons were considered to select the best season for maximum output, the dry season (April – August) and wet season (October – January). During the dry-season, a total harvest of 1127 fruits/200m$^2$ (or 5.635 fruits/m$^2$) was made, while 448 fruits/200m$^2$ (or 2.24fruits/m$^2$) were harvested during wet season (Table 1). Egusi require the use of chemical fertilizer to improve yield. At three (3) weeks, NPK green was applied and on 6$^{th}$ week, NPK blue was applied at the base of the crop. Lady bird insects were noticed to attack the leaves, and pesticide (Deltamethrin 2.8% w/w) was used subsequently after every two weeks, up to six times from germination to harvest (Table 2).

***Selected physical and mechanical properties of fruit***

The most important physical properties measured were the basic dimensions, mass, bulk density and sphericity, among others (Table 3). These properties are required for the design and development of planting, harvest and post-harvest operations (Bande *et al.,* 2012 a). The results showed that in 100 randomly selected fruits, the maximum length was 12.86cm and minimum was 5.73cm. The mean length of the fruits was 9.29cm. The width and thickness of the fruit were close to the length, giving a sphericity of about 1 (unity). The arithmetic and geometric mean diameters are functions of the basic dimensions, and thus their values were similar. Mechanical properties measured were vertical and horizontal loadings of the fruits, to determine the load resistance (Table 4), conducted using Instron machine (100kN, Bluegate 3 software). The horizontal and vertical loadings on the fruits were depicted as shown in Figures 4 and 5 respectively. The mean compressive mass obtained for vertical loading of fruit was 121.23kg with Standard deviation (SD) of 20.37kg. Maximum extension before rupture was 35.47mm and minimum extension was recorded as 26.86mm, with average value on three replicates as 29.94mm. The standard deviation was 4.79mm. For horizontal loadings, maximum mass to rupture of fruit was 82.81kg and minimum was 59.60kg with mean value of three replicates of 74.09kg and SD of 12.64kg. The maximum extension during the loading was 27.32mm, minimum of 25.57mm and mean extension of 26.29mm, with standard deviation of 0.914mm.

***Processing fruits for seeds***

With over 700 matured fruits harvested during dry season and about 344 matured during wet season, the fruit processing for seed involved cutting the fruit horizontally (Fig 2).

**Fig 1.** Whole Egusi fruit ready for harvest.

**Fig 2.** Horizontally cut fruit showing layout of seeds in the fruit before rotting

The cut fruits were heaped for 6 days to rot so that the seeds can be free from the flesh. The free seeds were then washed with ample water to remove dirt and pre-matured seeds, and sun dried for three days (Fig 3). Total mass of seeds obtained from dry season harvest was 45.5kg, while harvest from wet season produced only 5.49kg of seeds. Ten randomly selected fruits were collected and analysis on properties of fruits was made (Table 5). Average mass of fruit was recorded as 425.49g; average number of seeds per fruit was 330.6, with average mass of seeds recorded 65.652g/fruit. Average mass of fruit skin was recorded as 39.318g per fruit and average mass of fruit flesh was 320.52g.

**Table 3.** Physical properties of Egusi fruit as at time of harvest (MC = 84.01% w.b).

| Property | Reps | Max. | Min | Mean | SD | Mean* |
|---|---|---|---|---|---|---|
| Length (cm) | 100 | 12.86 | 5.73 | 9.29 | 1.67 | 9.6 |
| Width (cm) | 100 | 12.53 | 5.69 | 9.16 | 1.67 | 10.01 |
| Thickness (cm) | 100 | 15.52 | 5.62 | 10.57 | 2.90 | 9.85 |
| Mass (g) | 100 | 1031.6 | 103.5 | 407.2 | 219.03 | 500.46 |
| Arithmetic mean diameter | 100 | 13.63 | 5.68 | 9.67 | 2.07 | - |
| Geometric mean diameter | 100 | 13.22 | 5.58 | 9.42 | 1.98 | 9.82 |
| Sphericity (%) | 100 | 1.0 | 0.97 | 1.0 | 0.036 | 1.02 |
| Surface area ($cm^2$) | 100 | 549.18 | 97.90 | 291.19 | 117.97 | - |
| Aspect Ratio | 100 | 0.99 | 0.97 | 0.99 | 0.009 | - |
| Bulk density ($kg/m^3$) | 3 | 445.72 | 369.23 | 404.98 | 38.49 | - |
| True Density ($kg/m^3$) | 6 | 1237.82 | 993.48 | 1074.60 | 93.12 | 880 |
| Packaging coefficient | 5 | 43.54 | 28.18 | 33.49 | 6.27 | - |

Mean* (Akubuo and Adigboh, 1999)

**Fig 3.** Sun drying of seeds after washing, ready for further processing.

***Biomass and bio-energy of the crop***

Previous works reported on the crop indicated that it was grown only for its seed kernel (Girgis and Said, 1968; Makajuola, 1972; George *et al.*, 2010; Giwa et al. 2010); however, present work indicated that every part of the crop can be used as an energy source. Analysis on the biomass production was conducted on the crop, and it reveals that over 15 tons of biomass can be generated /hectare (or $1.5kg/m^2$) during dry season in Malaysia. It was also shown that about 2.3 tons of seeds can be produced/ha (or $0.23kg/m^2$) with over 1000 liters/ha (or $0.1liter/m^2$) of crude oil (Table 6). Energy generation from each component of biomass was also evaluated. Table 7 shows the energy generated during combustion process of individual biomass component. After soxhlet extraction of oil from 800g of the undehulled whole seed, 380ml of the oil (representing 44.79% or 358.84g) was obtained while for 800g dehulled seed kernel, 480ml (55.64%) oil, representing 444.96g crude oil was obtained. The remaining percentage was the by-product, which was reported to contain about 20% proteins (Eugene and Gloria, 2002) and used as livestock feed. Oils extracted from seed kernel; egusi dehulled seed oil (EDSO) and from whole seed; egusi whole seed oil (EWSO) were evaluated in terms of their properties. Works has been done on egusi seed kernel oil (EDSO) obtained from Nigeria, Benin and Cameroon, but no work was reported on EWSO. Table 8 shows the properties of both EWSO and EDSO and compares the results of EDSO of the current work and results of previous works on EDSO. Analysis on the methyl esters from both EDSO (EDSOME) and EWSO (EWSOME) was performed and were found to conform to biodiesel standards (ASTM and EN) and comparison of their properties with other biodiesels was presented (Table 9).

**Discussions**

The crop was planted at nursery level on clay and sandy-loam soils to observe their performance before field trial. After three (3) weeks of observations, crop on the clay soil exhibits a stunted growth, and eventually died due to compactness of the soil, while the sandy-loam crop had started flowering. A sandy-loam plot of $200m^2$ was utilized to grow egusi crop and was seeded on a two-seed per hole basis. First fruiting was observed during the $4^{th}$ and $6^{th}$ week of planting respectively for dry and wet seasons, 2 weeks earlier than reported growth in Nigeria in the former case (Ogbonna and Obi, 2007). The sign of maturity of the fruit was indicated by shading and drying of the leaves and stalk of the crop. This was noticed in the $15^{th}$and $17^{th}$week of planting for dry and wet seasons respectively. To enable more fruits mature, one week grace was allowed. Temperature throughout the dry season was predominantly $35^oC$, with rainfall data in the range of 75 to 175 mm. However, during the wet season, the temperature was in the range of 25 to $31^oC$, with rainfall greater than 450mm. The physical and mechanical properties (basic linear dimensions, mass, bulk and true densities, sphericity, aspect ratio, vertical and horizontal load bearing capacity of fruits as in Akar and Aydin, 2005; Aviara and Haque, 2000, Dutta, Nema & Bhardwaj, 1988; Garayak *et al.,* 2008; Akaaimo and Raji, 2006; Haque, Aviara & Mamman, (2000) on orange, Dinrifo and Faborode (1993), Shkelqim and Joachim (2010) on Jatropha seeds and kernels) were obtained and results shows a similar trend to crops such as *Prosopis Africana* (Akaaimo and Raji, 2006); Bambara

**Table 4.** Mechanical properties of Egusi fruit as at time of harvest (MC = 84.01% w.b).

| Property | Rep. | Max. mass (kg) | Min. mass (kg) | Av. Mass (kg) | SD (mm) | Max. Ext. (mm) | Min. Ext. (mm) | Av. Ext. (mm) | SD (mm) |
|---|---|---|---|---|---|---|---|---|---|
| Vertical loading | 3 | 133.95 | 97.93 | 121.23 | 20.37 | 35.47 | 26.86 | 29.94 | 4.79 |
| Horizontal loading | 3 | 82.81 | 59.60 | 74.09 | 12.64 | 27.32 | 25.57 | 26.29 | 0.914 |

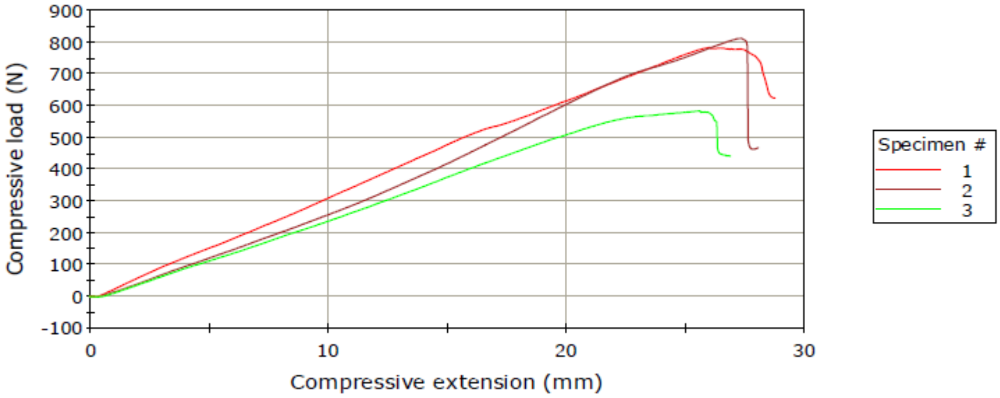


**Fig 4.** Horizontal loading on the fruit to determine maximum loading and extension fruit can withstand to rupture.

**Table 5.** Analysis for samples of ten fresh fruits.

| Sample | Mass of fruit (g) | No. of seeds | Approx. total mass of seeds (g) | Approx. total mass of fruit skin (g) | Approx. total mass of fruit flesh (g) |
|---|---|---|---|---|---|
| 1 | 681.80 | 428 | 109.08 | 61.36 | 511.35 |
| 2 | 540.40 | 394 | 82.14 | 48.64 | 409.62 |
| 3 | 423.30 | 367 | 63.5 | 40.21 | 319.59 |
| 4 | 209.80 | 187 | 33.36 | 18.88 | 157.56 |
| 5 | 417.70 | 371 | 64.74 | 38.43 | 314.53 |
| 6 | 514.80 | 381 | 77.22 | 46.33 | 391.25 |
| 7 | 573.20 | 402 | 87.13 | 55.6 | 430.47 |
| 8 | 188.30 | 156 | 28.06 | 17.14 | 143.11 |
| 9 | 384.70 | 321 | 61.55 | 35.78 | 287.37 |
| 10 | 320.90 | 299 | 49.74 | 30.81 | 240.35 |
| Total | 4254.9 | 3306.0 | 656.52 | 393.18 | 3205.2 |
| Ave./fruit | 425.49 | 330.6 | 65.652 | 39.318 | 320.52 |

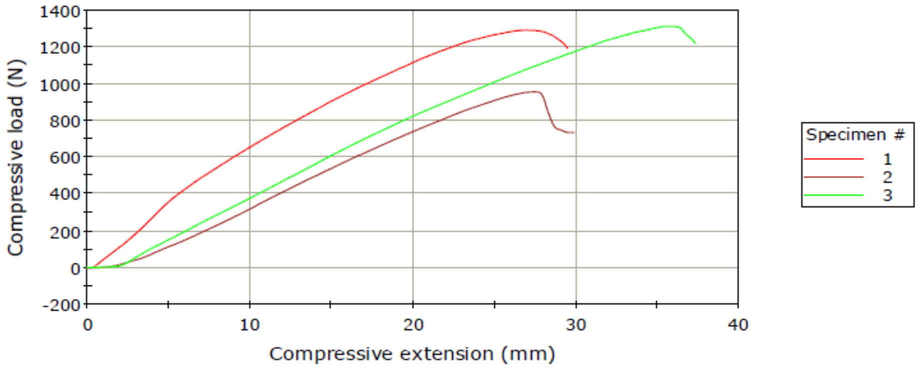


**Fig 5.** Vertical loading on the fruit to determine maximum loading and extension fruit can withstand to rupture.

groundnut (Baryeh, 2001); Cactus pears (Kabas, Ozmerzi & Akinci, 2005); Sorrel seed (Omobuwajo, Sanni & Balami, 2000); Bergamot fruit (Rafiee *et al.*, 2007). Fruits harvested were horizontally cut into two or three, depending on size. They were left to decompose until the seeds were free of the fruit, which took 6 days. Seeds were collected and washed thoroughly free of the remains of flesh, dirt and partially matured ones. They were then sun dried to the required moisture level for further processing. Moisture content determination was in accordance to ASAE S352 standard, as in the works of Dutta *et al.*, (1988); Baryeh (2001); Baumler *et al.*, (2006). The physicochemical properties of EDSO and EWSO as presented in Table 8 shows good conformity to ASTM standard of biodiesels. Comparison of EDSO with previous studies shows that the findings are within same range. EWSO shows lower density and saponification value than EDSO but higher Calorific value, Iodine and Acid values. After transesterification process, EDSO methyl ester (EDSOME) and EWSO methyl ester (EWSOME) were obtained and all fuel properties fall within the ranges of both ASTM and EN standards (Table 9). EWSOME had lower cloud point than EDSOME indicating better operating

**Table 6.** Estimated output from the biomass.

| **Part** | kg/200m$^2$ | Quantity (kg/ha) |
|---|---|---|
| Seeds | 45.96 | 2,298.00 |
| Crude oil | 19.54 kg<br>Or 21.831 liters | 977 kg<br>Or 1,091.5 liters |
| Feed | 26.42 | 1,321.00 |
| Roots | 10 | 500.00 |
| Stalk | 80 | 4,000.00 |
| Leaves | 110 | 5,500.00 |
| Fruit skin | 27.52 | 1,376.00 |

**Table 7.** Energy generation by biomass components.

| Component | Energy Output (MJ/kg) | Quantity /ha (kg) | Energy Output (MJ/ha) |
|---|---|---|---|
| Crude oil | 45.42 | 19.54 kg or<br>1,091.50 liters | 887.507 |
| Livestock Feed | - | 1,321.00 | |
| Roots | 11.94 | 500.00 | 5,970.00 |
| Stalk | 18.41 | 4,000.00 | 73,640.00 |
| Leaves | 20.43 | 5,500.00 | 112,365.00 |
| Fruit skin | 27.31 | 1,376.00 | 37,578.56 |

**Table 8.** Physicochemical properties of crude oils of EWSO and EDSO.

| Property | Unit | Standard | EWSO | EDSO |
|---|---|---|---|---|
| Kinematic viscosity @40$^o$C | mm$^2$/s | ASTM D445 | 13.14 | 7.0, 31.52$_a$, 20$_b$ |
| Calorific value | MJ/kg | ASTM D240 | 45.0 | 41.7, 39.37$_a$ |
| Density @15$^o$C | Kg/m$^3$ | ASTM D4052 | 897.96 | 906.82, 905.3$_a$, 960$_b$ |
| Iodine value | gI$_2$/100g | - | 116.1 | 114.3, 114.46$_a$ |
| Saponification value | mgKOH/g | - | 201.87 | 212.36, 204.44$_a$ |
| Acid value | mgKOH/g | ASTM D664 | 1.456 | 1.08, 0.98$_a$, 1.06$_b$ |

a = (Giwa *et al.* 2010), b = (Bello and Makanju, 2011)

condition in low temperate regions and also lower acid value and flash point. The Cetane number and calorific value in EWSOME was higher than those found for EDSOME, indicating possible better performance in combustion process output. In comparison to other similar oil crops, both EWSOME and EDSOME have lower acid value and kinematic viscosities than methyl esters of sunflower and safflower and about same Cetane number and calorific number with both, indicating both EWSOME and EDSOME as better biodiesels. Density of both EWSOME (870.96kg/m$^3$) and EDSOME (876.70 kg/m$^3$) were lower than values reported for sunflower and *Pongamia pinnata* and about same with that reported for safflower, but with almost same value of ester content.

## Material and Methods

### *Experimental site and soil characteristics*

Two experimental planting plots of 200m$^2$ area were utilized for the experiment; Clay-soil site (located at about 2$^0$ 59' north latitude and about 101$^0$ 42' east longitude) and sandy-loam soil site (located at about 3$^0$ 0' north longitude and 101$^0$ 42' east longitude) at planting fields of Universiti Putra Malaysia from March 2012 to January 2013. The soil was slightly acidic (pH 6.2) and low in organic matter (1.2%).

### *Plant materials and growth conditions*

The plant material used was egusi (*Citrullus lanatus*) obtained from Nigeria for the purpose of the fundamental research. The seeds were manually cleaned and selected for planting after rotavation of both planting plots and ridge making. Planting was done on standard spacing of egusi (100 ±10cm) in between rows and individual spacing, on two seeds per planting hole basis. NPK fertilizers (green and blue) were applied twice from planting to harvesting and insecticide (Deltamethrin 2.8% w/w) on six occasions to harvest as insects attack leaves of the crop.

### *Trait measured*

The response of the crop in sandy-loam soil was good at nursery level and at experimental plot during dry season in Malaysia. The number of fruits obtainable per m$^2$, the average size of fruits, the mean number of seeds per fruit and per m$^2$, the approximate biomass per m$^2$, the physical and mechanical properties of fruits and approximate oil production capacity of the crop per m$^2$ were measured. Biomass components of the crop were the roots, stalk, leaves and fruit skin. The samples were collected and sundried then oven dried until the moisture contents were between 7.11% and 7.28% d.b. Oxygen bomb calorimeter was used to determine the calorific values of 1g of each sample in kJ/kg. The values estimated per m$^2$ of the biomass were then used to estimate the energy generation by individual component.

### *Physicochemical and fuel properties of egusi oils*

The physicochemical properties measured were the acid value, density, kinematic viscosity and calorific values of both EWSO and EDSO prior to transesterification process to methyl ester. The acid value will guide either single-stage or double-stage transesterification, and density will give an idea

**Table 9.** Fuel properties of EDSOME and EWSOME and other biodiesels.

| Fuel property | Unit | Standards Limits | | EDSOME | EWSOME | EMOME | Pongamia Methyl Ester | Sunflower Methyl Ester | Safflower Methyl Ester |
|---|---|---|---|---|---|---|---|---|---|
| | | ASTM D6751 | EN 14214 | | | | | | |
| Pour point | °C | -15 to 10 | - | 0.33 | -0.33 | -6[e] | -13[f] | - | - |
| Cloud point | °C | -3 to 12 | Report | 1.17 | 0.67 | 0.5[d], -5[e] | -6.5[f] | 1[b] | 2[c] |
| K/viscosity @40°C | mm$^2$/s | 1.9-6.0 | 3.5-5.0 | 3.00 | 2.53 | 3.83[d], 3.95[e] | 7.532[f] | 4.85[b] | 4.29[c] |
| Ester content | %(mol/mol) | - | 96.5 min | 97.27 | 97.19 | 96.78[d] | - | 97.2[a] | 97.67[c] |
| Flash point | °C | 130 min | 120 min | 145.33 | 142.67 | 142.0[d], 150.0[e] | 90[f] | 168[b] | 176[c] |
| Acid value | mgKOH/g | 0.5 max | 0.5 max | 0.168 | 0.14 | 0.19[d], 0.20[e] | - | 0.4[a] | 0.28[c] |
| Cetane number | | 47 to 65 | - | 52.54* | 53.06* | 53.66[d], 53.56[e] | 53[f] | 55[b] | 52.32[c] |
| Density @ 15°C | Kg/m$^3$ | - | 860-900 | 876.70 | 870.96 | 883[d], 910[e] | 905.4[f] | 884[b] | 874[c] |
| Calorific value | MJ/kg | - | - | 45.52 | 45.72 | 39.97[d], 39.0[e] | - | 45.5[c] | 45.21[c] |
| Linolenic Acid | %(mol/mol) | - | 12.0 max | 0.04 | 0.09 | 0.38[d], 1.44[e] | - | 0.2[a] | - |

* are values of Cetane numbers of EDSOME and EWSOME, determined empirically as in Tsanaktsidi and Tzilantonis (2010), Ramos *et al.*, (2009) and Moser (2009). a = (Ramos *et al.*, 2009), b = (Rashid, Anwar & Arif, 2009), c = (Rashid and Umar, 2008), d = (Giwa *et al.* 2010), e = (Bello and Makanju, 2011), f = (Pradip *et al.*¸2010).

of the methyl ester density while kinematic viscosity will show the reduction after the transesterification process. The crude oils were transesterified with KOH as catalyst (0.55% of weight of oil) and methanol as alcohol at 60$^0$C for 1 hour @ 360rpm in the transesterification reactor (condenser unit incorporated) until complete reaction. The transesterified product was poured in a funnel overnight for complete separation of glycerol and biodiesel layers. Glycerol (higher density at lower layer) was siphoned out through the funnel and methyl ester was left in the funnel. Luke warm deionized water was used to wash off the soap, until the water at the bottom of the funnel was clear, and then drained off completely from the funnel. The biodiesel was then centrifuged for 30 minutes @ 2000rpm and room temperature to obtain complete separation from water particles, followed by drying in oven at 105±2$^0$C for 2 hour to remove excess water particles.

## Conclusion

In the present study, it was concluded that egusi crop adapt to Malaysian environment with possible fruit production of over 1100 on a 200m$^2$ plot. The oil production from the seeds grown in Malaysia has produced 2.64% more than reported in literature, with possibility of obtaining 2.2 tons of seeds/ha and high potential of high quality biodiesel and biomass.


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