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Comparison of oil quality extracted from selected conventional and non conventional sources of vegetable oil from Malawi

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In this study, oil quality with respect to physicochemical and phytochemical characteristics extracted from nonconventional seed oil namely *Moringa oleifera*, *Adansonia digitata*, *Parinari curatellifolia* and *Cajanus cajan* and conventional seed oil namely soybean (*Glycine max*) and groundnut (*Arachis hypogaea*) was assessed and compared. Results showed that there were significant differences in various quality parameters such as saponification number, peroxide value, free fatty acids in oils extracted from non-conventional and conventional sources. Oil yield ranged from 4.71 to 46.05% with pigeon peas registering the lowest yield and *P. curatelifolia* registering the highest yield. The following range of values in quality parameters were obtained: values in saponification number ranged from 55.91 mg KOH/g (*C. cajan*) to 220.54 mg KOH/g (groundnut): Peroxide value ranged from 2.79 meq O_2/kg (*M. oleifera*) to 10.47 meq O_2/kg (*C. cajan*): Free fatty acids ranged from 1.11 mg/100 g (*P. curatelifolia*) to 4.80 mg/100 g (pigeon peas): Specific gravity ranged from 0.87 (*P. curatelifolia*) to 0.91 (groundnuts): Oxalate ranged from 75.41 mg/100 g (groundnuts) to 632.56 mg / 100 g (pigeon peas): Acid value ranged from 2.21 mg KOH/g (*P. curatelifolia*) to 9.53 mg KOH/g (Pigeon pea): Iodine value ranged from 35.53 g/100 g (*P. curatelifolia*) and alkaloids ranged from 58.28 mg/g (*M. oleifera*) to 123.60 mg/g (groundnuts). Irrespective of the source of the oils, it was observed that the values in most of the oil quality parameters were within the acceptable levels. The findings in this study have demonstrated that nonconventional sources of oil have the potential to adequately supplement oils used for domestic consumption as well as industrial use in Malawi and therefore reduces the volumes of imported oils hence safeguarding foreign reserves.

Key words: Phytochemical, physicochemical, oil quality, *Moringa oleifera*, *Parinari curatellifolia*, *Adansonia digitata*.

INTRODUCTION

The world demand for fixed oils (vegetable oils and fats) is increasing with a consequential increase in prices (Mielke, 2017). Universally, vegetable oil consumption is mainly based on soybean, palm, rapeseed and sunflower oil with 31.6, 30.5, 15.5 and 8.6 million tons consumed annually respectively (Stevenson et al., 2007). These

conventional sources of fixed oil fall short in meeting up the spiking demand of oil from both domestic and industrial sectors (Idouraine et al., 1996; Kojima et al., 2006).

Over the years, studies have been extensively carried out on the chemical composition of oil seeds of leguminous plants (Rusníková et al., 2013) and indigenous fruits (Abiodun et al., 2012; Edogbanya, 2016). Legume seeds play important role in human (Nwosu and Ojimelukwe, 1993; Mbagwu et al., 2011) as well as animal nutrition contributing almost one-third of dietary protein (Graham and Vance, 2003; Rusníková et al., 2013). Legume seeds have been reported to have low fixed oil production with the exception of soybean (Rusníková et al., 2013) which has 22.7±0.5 % oil content (Siulapwa and Mwambungu, 2014). On the other hand, pigeon pea (*Cajanus Cajan)* has been reported to contain 2.74% oil (Adebowale and Maliki, 2011) whereas groundnut (*Arachis hypogaea*) is reported to contain 39.10% oil (Kumar et al., 2013).

Indigenous tree seeds such as *Moringa oleifera* (Anwar et al., 2005), *Parinari curatellifolia* (Ndabikunze et al., 2006) and baobab (*Adansonia digitata*) seeds (Igboeldi et al., 1997; Abubakar et al., 2015) contain high amount of oil. Moringa is a domestic tree with various uses as food and medicine. It grows in the Middle East, tropics and subtropical areas of the world (Foidl et al., 2001). Moringa seed kernel contains 40% oil and 70% free fatty acids as oleic acids (Anwar et al., 2005). Moringa seed oil, commercially known as “Ben or Behen oil,” has properties that make it suitable for human consumption (Leone et al., 2016). Baobab (*A. digitata*) tree belongs to the Bombacaceae family and sub-family Malvaceae (Bremer et al., 2003; Osman, 2004) and is one of the underutilized crops in Africa (Temu et al., 2016). *A. digitata* seeds contain 12.20±0.1% (Osman, 2004) and 34.1±0.2 (Ikemefuna and Amaechi, 1992; Ezeagu, 2005) oil.

P. curatellifolia, locally known as Maula in Malawi, belongs to the *Chrysobalanceae* family (Oladimeji and Bello, 2011). It is a tropical evergreen tree that grows in sandy loam soil (FAO, 1982) and produces 47% oil from the nuts (Kernels) (Ndabikunze et al., 2006). Oilseeds have paramount importance in economics, nutrition and technology aspects. Oil produced from oilseeds is used in cooking, making soaps, cosmetics, lubricants, greases and agrochemicals (Idouraine et al., 1996; Nadeem and Imran, 2016). Fixed oils constitute part of our diet in supplying nutrients and energy to our bodies as well as flavor to our food (Atasie et al., 2009). Oils are sources of fat soluble vitamins like anti-oxidant vitamin E and protect sensitive or damaged cells from infections (Atasie et al., 2009). It is recommended that 40% of human energy requirements should come from fats and oils besides nutrients provision (Sarwar et al., 2013).

Despite the main uses that oils possess, there is no single oil source that is suitable for all uses because of differences in their oil composition (Joshi et al., 2012). The quality of these oils for dietary purposes is based on parameters like acid value/free fatty acids, saponification values, peroxide value, and iodine value (Mousavi et al., 2012) besides the fractions of saturated and unsaturated fatty acid present in the oil (Rusníková et al., 2013). Based on this background, it is of paramount importance to intensify research on various aspects of oils such as in developing cooking oil supplies from non-conventional sources like Moringa seeds, *P. curatellifolia*, *A. digitata* and pigeon peas (*Cajanus cajan*). The objective of this current study was therefore to compare the oil quality parameters with respect to physicochemical and phytochemical characteristics in oils extracted from non-conventional and conventional sources of oil grown in Malawi.

MATERIALS AND METHODS

Sample collection and preparation

Moringa oleifera and *P. curatellifolia* seeds were obtained from communities surrounding Lilongwe University of Agriculture and Natural Resources, Bunda College Campus and Bunda forest respectively whereas *A. digitata* fruit seeds were bought from Mtchesi market in Lilongwe district. *A. digitata* seeds were washed in distilled water to separate the seeds from the pulp. Sundried woody *P. curatellifolia* seed stones, whose pulp were eaten by birds were collected from the ground below/underneath the trees. The seed kernels were removed from the woody seed stone by crushing the stones with a hard stone (Figure 1).

Soybean (*Glycine max*) seeds, pigeon pea (*C. cajan*) seeds and groundnuts (*Arachis hypogaea*) locally known as Nambwindi were bought from Mitundu local market, in Lilongwe district. *M. oleifera*, *Glycine max*, *C. cajan* and *A. hypogaea* (Nambwindi) seeds were manually sorted to remove dust, stones and those seeds infected by diseases (Olawumi et al., 2012). Dried samples were ground through a 1 mm sieve using a Thomas-WILEY model 4 Laboratory Mill before analyzing the physicochemical properties. The ground samples were used to analyze the qualities of crude fat using Association of Official Analytical Chemists (AOAC), 1996 methods with minor modifications.

Oil extraction procedure

Oil from the different samples was extracted by using petroleum ether in a soxhlet extractor / apparatus for 16 h. 20 g of finely ground sample was put into a porous thimble in a soxhlet apparatus connected to a weighed 250 ml flat bottomed quick fit flask containing 200 ml petroleum ether. The solvent was continuously boiled at 40 to 60°C extracting the fat from the sample. After 16 h of extraction the petroleum ether was evaporated by using a rotary

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Figure 1. Removing kernels from the stones.

evaporator. The flask containing the crude oil was then dried to constant weight at 105°C in the laboratory oven for 2 h. The crude oil was then refrigerated at 10°C in tight closed plastic bottles with no any further treatment waiting for some analysis (Adegbe et al., 2016).

Physicochemical analysis of oils

The determination of the physico-chemical properties of the oil followed the AOAC, 1996 methods with minor modifications.

Oil percentage

Following oil extraction method as described above, the oil percentage was calculated as in Equation 1.

$$\text{Oil \%} = \frac{(A-B)}{W} \quad (1)$$

Where: A= Weight of flask and oil after extraction (g)
B= Weight of flask only (g)
W = Weight of sample (g)

Determination of saponification value (SV)

1.0 g of the oil was weighed in a conical flask and 50 ml of 1.0 M ethanolic potassium hydroxide (KOH) was added. The flask was connected to a reflux condenser and was refluxed for 1 h until the solution became clear. A blank sample containing only 50 ml ethanolic Potassium hydroxide was similarly treated as the sample. The solution was then titrated to a faint pink colour end point against 1.0 M Hydrochloric acid (HCl) using phenolphthalein indicator (Ogungbenle and Sanusi, 2015). Saponification value (SV) was calculated as shown in Equation 2 below:

$$\text{SV (mg KOH / g)} = \frac{(A-B) \times N \times 56.02}{W} \quad (2)$$

Where: A= Blank ethanolic HCl volume in ml
B= Sample ethanolic HCl volume in ml
N= Normality of HCl, W=Weight of sample / oil in grams.

Determination of acid value (AV)

1.0 g of oil was weighed in a 250 ml conical flask containing 25 ml of absolute ethanol and diethyl ether (1:1) solution. The mixture was heated in a warm water bath (40°C) for 5 min and 3 drops of phenolphthalein indicator was added. The mixture was titrated against 0.1 M potassium hydroxide (KOH) to a faint pink color that persisted for 30 s. Acid value was then calculated as in Equation 3:

$$\text{Acid value (mg KOH/g oil)} = \frac{\text{ml (KOH)} \times N \times 56.1}{W} \quad (3)$$

Where N = Normality of KOH, W = Weight of oil sample in grams

Determination of free fatty acids (FFA)

Free fatty acids are the resultant of glycerin decomposition in oils and is measured as the number of milligrams of KOH required to neutralize a unit mass of oil. Therefore FFA value was analyzed by titrating 1.0 g of oil dissolved in 25 ml of absolute ethanol: diethyl ether (1:1 V/V) against 0.1 M ethanolic KOH to a faint pink color using phenolphthalein indicator. FFA is expressed as oleic acid equivalent and 0.1 M KOH = 28.2 g oleic acid as presented in Equation 4 (Okene and Evbuomwan 2014):

$$\text{FFA (g / 100 g as oleic acid)} = \frac{\text{Titre volume (ml) of KOH} \times 0.1\ N \times 28.2}{W} \quad (4)$$

Where N = Normality of ethanolic KOH, W = Weight of sample of oil in grams

Determination of peroxide value (PV)

1.0 g of oil sample was weighed into a 250 ml conical flask containing 20 ml of glacial acetic acid: chloroform solvent (3:2 v/v). 1.0 ml of saturated potassium hydroxide was then added to the mixture in the conical flask and was kept in the dark for 1 min. 30 ml of distilled water was added and the solution was titrated against 0.1 M Sodium thiosulphate ($Na_2S_2O_3$) solutions using 5 ml of starch as an indicator. A blank sample was treated as the samples. Equation 5 was used to obtain results which were expressed as meq per kilogram (Ogbunugafor et al., 2011).

$$PV\ (meq\ O_2/Kg) = \frac{((V_2-V_1) \times M) \times 1000}{W} \quad (5)$$

Where V_1= Titre volume in ml of 0.1 M $Na_2S_2O_3$ for blank, V_2 = Titre volume in ml for sample, W = Weight of oil sample in grams.

Determination of iodine value (IV)

In determination of the iodine value (IV) of the oil, the methods described by the Association of Official Analytical Chemists (AOAC), 1996 and Choudhary and Pande (2000) methods were used with minor modifications in replacing carbon tetrachloride with cyclohexane.

0.5 g of oil was weighed in a 250 ml conical flask and 20 ml of cyclohexane: glacial acetic acid (1:1 V/V) solution was added into the flask. 10 ml of Wijs reagent was added to the flask, thoroughly mixed and kept in the dark for an hour. 15 ml and 100 ml of 15% Potassium iodide (KI) and distilled water were added to the flask and the solution was titrated against 0.1 M Sodium thiosulphate ($Na_2S_2O_3$) solution to colorless end point using starch as an indicator. The IV was calculated as shown in Equation 6:

$$IV\ (g\ I_2/100\ g) = \frac{(B-S) \times M \times 126.9 \times 100}{W\ (g) \times 1000} \quad (6)$$

Where B= Volume 0.1 M Sodium thiosulphate used in titrating the blank
S=Volume of 0.1 M Sodium thiosulphate used in titrating the sample
126.9= Molar mass of iodine
M= Molarity of Sodium thiosulphate
W=Sample weight in grams

Ester value (EV)

This is the milligrams of KOH that react with glycerin after saponification of a unit gram of oil. Therefore the EV was calculated as the different between the saponification value (SV) and acid value (AV) as shown in Equation 6.

Ester value = saponification value – Acid value (7)

Determination of oil refractive index

Refractive index was measured using Bellingham and Stanley No.A83304 refractometer. A drop of oil was placed on the lower prism and the prism box was closed. The water flowed through the equipment jacket at 25°C, the light was adjusted then the compensator knob was moved to get a dark borderline on the cross wires which was viewed through the refraction view piece. The reading was recorded from the scale view through eyepiece (Ogungbenle, 2014).

Calculation of specific gravity

The specific gravity of the extracted oils was determined by calculation using the Lund equation as described by Halvorsen et al. (1993).

Specific gravity = 0.8475 + 0.0003SV + 0.00014IV (8)

Where SV is saponification value and IV is iodine value.

Phytochemical chemical analysis of oils

Phytic acid determination

2 g of the sample was dissolved in 2% hydrochloric acid for 3 h and was filtered through Schleicher and Schuell 270 mm filter paper. 25 ml of the filtrate was mixed with 5 ml of ammonium thiocyanate and the mixture was titrated against 1.04% iron / Ferric chloride to brownish yellow color that persisted for 5 minutes (Reddy et al., 1992).

Alkaloids determination

5 g of the sample was dissolved in 20% Acetic acid in ethanol and the solution was left to stand for 4 h. The solution was filtered and was evaporated to one fourth of the solution. Concentrated ammonium hydroxide was added to the solution drop wise till precipitation was complete. The precipitate was filtered and dried in the drying oven to constant weight (Obadoni and Ochuko, 2001).

Oxalate determination

1 g of the sample was dissolved in 75 ml of 1.5 M Sulphuric acid and was stirred for 1 h and filtered. 25 ml of the filtrate was titrated while hot against 0.05 M potassium permanganate to a faint pink color that persisted for 30 s. Oxalate content was calculated as follows: 1 ml of 0.05 M $KMno_4$ = 2.2 mg Oxalate (Chinma and Igyor, 2007).

Flavonoids determination

10 g of the sample was extracted with 300 ml of methanol: water (80:20 v/v) at room temperature for 1 h. The solution was filtered through a 125 mm whatman filter paper. The filtrate was transferred into a weighed crucible and evaporated to constant weight (Boham and Kocipai–Abyazan, 1974; Obadoni and Ochuko, 2001).

Statistical analysis

Data were analyzed using Statistical Package for Social Sciences (SPSS) version 16. Analysis were done in triplicates and presented as means ±SE. Analysis of Variance (ANOVA) with post-hoc was used to analyse and evaluate mean difference with a probability value of less than 0.05 being regarded as statically significant.

RESULTS AND DISCUSSION

Results on the physicochemical properties of the extracted oils are presented in Table 1.

Oil yield composition

Results on oil yield ranged from 46.05±0.19% to 4.71±0.12% for *P. curatellifolia* and *C. cajan* respectively. Values obtained for *M. oleifera* of 34.91±0.93% was slightly lower than the values of 38 and 45.8% reported by other researchers (Adegbe et al., 2016; Abiodun et al.,

Table 1. Physicochemical properties.

Parameter	*M. oleifera*	*P. curatellifolia*	*A. digitata* seeds	Pigeon pea (*C. cajan*)	Soybean (*G. max*)	Groundnut (*A. hypogeae*)
oil %	34.91±0.93[a]	46.05±0.19[b]	31.65±0.44[c]	4.71± 0.12[d]	19.32±0.36[e]	20.70±0.28[f]
Saponification value (mg KOH / g)	136.65± 0.14[a]	90.09±0.30[b]	122.54±0.11[c]	55.91±0.06[d]	55.93±0.02[e]	220.54±1.76[f]
Acid value as oleic (mg KOH / g)	9.46±0.02[a]	2.21±0.01[b]	2.21±0.01[b]	9.53± 0.17[a]	5.36±0.09[c]	2.68±0.01[d]
Peroxide value (meq O_2 / Kg)	2.79±0.00[a]	2.79±0.00[a]	2.81±0.02[a]	10.47± 0.12[b]	5.18±0.21[c]	2.85±0.06[a]
Iodine value (g I_2 / 100 g)	43.11±6.81[a]	35.53±4.59[b]	40.87±3.14[c]	69.64± 5.19[d]	52.23±3.95[d]	53.30±6.54[e]
Free Fatty Acids (mg / 100 g)	4.76±0.01[a]	1.11± 0.00[b]	1.11±0.00[b]	4.80±0.09[c]	2.63±0.05[d]	1.35±0.01[e]
Ester value (mg KOH / g)	127.18±0.13[a]	127.18± 0.13[a]	120.33±0.11[b]	46.35± 0.15[c]	50.69±0.07[d]	217.86±1.75[e]

For each parameter, means with same superscript were not significantly different (P>0.05).

2012). However, the value was in agreement with the work of other researchers in Sudan who reported a value of 34.8% (Anwar and Rashid, 2007). The oil content in *P. curatellifolia* kernel of 46.05±0.19% was found to be higher than 1.77% as compared to results obtained by other researchers (Ogungbenle and Atere, 2014) and 5.11±0.10% (Oladimeji and Bello, 2011) reported in Nigeria. However, it was closely similar to the value of 47% which was reported by other researchers (Ndabikunze et al., 2006) for studies conducted in Tanzania. On the other hand, *A. hypogaea* and *G. max* had similar oil yields of 20.70±0.28% and 19.32±0.36% which were lower than the value of 47.00±0.03% reported by other authors in a related study conducted in Nigeria (Atasie et al., 2009). However, the yield value of oil obtained in *A. digitata* seeds of 31.65±0.44% was in agreement with the value of 32±0.00 previously reported by other researchers (Abubakar et al., 2015).

Saponification value composition

Results showed differences in the values of saponification value for the two sources of oil as well as values obtained by other researchers in previous studies. Groundnut (*A. hypogaea*) oil had the highest saponification value followed by *M. oleifera*, *A. digitata*, *P. curatellifolia*, *G. max* and *C. cajan* oils respectively. The saponification value of 220.54±1.76 mg KOH/g oil obtained in *A. hypogaea* was higher than 193.20 mg KOH/g (Atasie et al., 2009) for *A. hypogaea* oil obtained by other researchers in Nigeria. On the other hand, the saponification value in *M. oleifera* oil of 136.65±0.14 mg KOH/g was low compared to the value of 180.92 as reported previously by other researchers (Adegbe et al., 2016).

The saponification value for *P. curatellifolia* oil of 90.09±0.30 was lower than 135.1 reported in a study conducted in Zimbabwe (Ndaba, 2014).

Similarly, *A. digitata* seed oil saponification value of 122.54±0.11 was lower than 158.62±0.07 (Abubakar et al., 2015) as reported in Nigeria but higher than that of G. max and C. cajan oils obtained from this study. On the other hand, the saponification value of 55.93±0.02 for G. max was higher than 13.47±0.06 mg KOH/g (Essien et al., 2014). Interestingly, it was observed that the saponification values of crude oils were within the recommended values of 180-199 mg KOH/g oil (FAO/WHO, 2009) for edible oil, 187-196 (FAO, 1995) and 189-195 mg KOH/g (FAO, 1995) for A. hypogaea and G. max oils. As reported by various authors, saponification value measures the oxidation state of the oil (Nkafamiya et al., 2010), type of fatty acids in oils (Adejumo et al., 2013) and average molecular weight of the oils (Preeti et al., 2007). The different oil quality characteristics that saponification value measures as well as the differences in the way the oils were processed and handled in the different countries probably might have explained the reasons for the differences in the values obtained in this study. The high saponification values of the oils indicate oxidative state of the oils and the low values indicate the onset of oxidation (Nkafamiya et al., 2010).

Acid value composition

Results showed that *C. cajan* and *M. oleifera* had the highest acid values of 9.53±0.17 and 9.46±0.02 mg KOH/g oil followed by *G. max* oil (5.36±0.09), *A. hypogaea* oil (2.68±0.01), *P. curatellifolia* (2.21±0.01) and *A. digitata*

(2.21±0.01). *A. hypogaea* acid value of 2.68±0.01 was lower than 5.99 mg KOH/g as reported by other researchers (Atasie et al., 2009) for studies done in Nigeria. Compared with values obtained from other studies, it has been observed that *M. oleifera* oil had acid value higher than 6.73 (Adegbe et al., 2016) and 7.09±0.21 (Abiodun et al., 2012) for studies conducted in Nigeria. The *A. digitata* acid value of 2.21±0.01 was found to be low as compared to 6.52±0.02 (Oyeleke et al., 2012) but was closely in agreement with 2.75±0.14 reported by Abubakar et al. (2015) in a related study conducted in Nigeria. *G. max* had acid value of 4.05±0.024 which was higher than the value reported by Okorie and Nwachukwu (2014). The acid values for *M. oleifera*, *C. cajan* and *G. max* oils obtained in this study were higher than the recommended value of 4.0 mg KOH/g oil for edible virgin and cold pressed oils whereas *P. curatellifolia*, *A. hypogaea* and *A. digitata* oil acid values were below the recommended standard of 4.0 mg KOH/g oil (FAO/WHO, 1999).

Acid value measures the degree of oil spoilage, in terms of free fatty acids (FFAs), from enzymatic activity (Amadi et al., 2013). This observation of high acid values in *M. oleifera*, *C. cajan* and *G. max* oil suggest that these oils contain higher levels of fatty acids, as oleic acids, than *P. curatellifolia*, *A. digitata* and *A. hypogaea*.

Peroxide value composition

Results on peroxide value similarly showed that there are differences in values for the two sources of oil. Peroxide values of crude oils ranged from 2.79±0.00 to 10.47±0.12 meq O_2/kg oil for *M. oleifera* and *P. curatellifolia* oils. The *A. hypogaea* peroxide value of 2.85±0.06 meq O_2/kg was closely similar to that of *A. digitata*, *P. curatellifolia* and *M. oleifera* oil registering 2.81±0.02, 2.79±0.00 and 2.79±0.00 meq O_2/kg oil respectively. When compared with values previously reported by other authors, it was observed that peroxide value in *M. oleifera* was similar to 2.60 meq O_2/kg (Adegbe et al., 2016) but higher than the value of 0.83±0.13 meq O_2/kg (Basuny and Al-Marzouq, 2016) and interestingly lower than the value of 15.96±0.13 meq O_2/kg (Abiodun et al., 2012) reported in studies conducted in Nigeria and Saudi Arabia. However, *A. digitata*, *P. curatellifolia* and *A. hypogaea* oils peroxide values were higher than the value of 1.5 (Atasie et al., 2009) for *A. hypogaea* oil reported in related studies. *G. max* had higher acid value of 5.18±0.21 than the value of 2.42±0.06 meq O_2/kg (Okorie and Nwachukwu, 2016) for *G. max* oil studies conducted in Nigeria.

The values obtained in *M. oleifera*, *A. digitata*, *G. max* and *P. curatellifolia* oils were found to be within the recommended value of 5.0 meq O_2/kg oil (FAO/WHO, 1999) for edible fat and oils whereas *C. cajan* peroxide value was within the recommended value of 10.0 meq O_2/kg oil (FAO/WHO, 1999) for edible virgin and cold pressed fat and oils. Peroxide value measures the degree of either the occurrence of peroxidation or adulteration (Okene and Evbuomwan, 2014) and could be used to evaluate the quality and stability of oils during storage (Adejumo et al., 2013; Okene and Evbuomwan, 2014). Therefore the low peroxide values in *M. oleifera, P. curatellifolia, A. digitata and A. hypogaea* oils indicate that these oils are more saturated than *C. cajan* and *G. max* oils and therefore the low peroxide value reflects high quality in the oils.

Iodine value composition

Results showed that there were differences in iodine value composition for the two sources of vegetable oils. The iodine value for the extracted oils ranged from 35.53±4.59 to 69.64±5.19 g I_2/100 g for *P. curatellifolia* and *C. cajan* respectively. The iodine values for *M. oleifera* and *A. digitata* were very close as reflected by the recorded values of 43.11±6.81 and 40.87±3.14 respectively. On the other hand, *A. hypogaea* and *G. max* oils had similar iodine values of 53.30±6.54 and 52.23±3.95 which were lower than the value of 69.64±5.19 for *C. cajan* obtained in this study. When compared with findings from other authors, it was observed that the *M. oleifera* iodine value of 43.11±6.81 was lower than of 55.02±0.15 (Abiodun et al., 2012) and 68.41 (Siyanbola et al., 2015). On the other hand, *G. max* and *A. hypogaea* oil had low iodine values as compared to the values of 123.42 (Eze, 2012) and 38.71 (Atasie et al., 2009) for *G. max* and *A. hypogaea* reported in studies conducted in Nigeria. Similarly, values obtained in *A. digitata* reveled low iodine value of 40.87±3.14 as compared to the value of 54.41±0.94 (Abubakar et al., 2015) reported in studies conducted in Nigeria. The iodine values of the extracted crude oils were lower than the recommended iodine values of 90-115 g I_2/100 g oil for crude vegetable oil (FAO/WHO, 2009).

Iodine value measures the degree of unsaturation (number of double bonds) of the oils. The high iodine value reflects high degree of unsaturation (more double bonds) of the oils meaning that the oils easily undergo oxidation and rancidification reaction (Egbuonu et al., 2015). The low iodine values for the extracted oils observed in this study suggest that the oils are saturated and therefore have low susceptibility to oxidation and rancid reaction during storage.

Ester value composition

Results on ester value ranged from 46.35±0.15 to 217.86±1.750 mg KOH/g oil for *A. hypogaea* and *C. cajan* oils. Interestingly, *M. oleifera* and *P. curatellifolia* had similar ester values of 127.18±0.13 mg KOH/g oil which were higher than that of *A. digitata, C. cajan* and *G. max* but lower than 217.86±1.75 for *A. hypogaea* oil.

Free fatty acid composition

Results on free fatty acid composition showed that the values ranged from 1.11±0.0 to 4.80±0.09 mg KOH/g oil with *P. curatellifolia* and *A. digitata* registering the lowest values and Moringa and *C. cajan* the highest values. *A. hypogeae* free fatty acid value of 1.35±0.01 was lower than the value of 3.01 mg KOH/g oil obtained by other researchers (Atasie et al., 2009) for work conducted in Nigeria. Contrastingly, the *M. oleifera* fatty acid value of 4.76±0.01 was higher than the value of 2.8 and 3.3 (Anwar et al., 2006) for drought and irrigated *M. oleifera* and lower than the value of 11.2 for n-hexane extracted Moringa oil (Lalas and Tsaknis, 2002) obtained in related studies. The observed acid values for crude oils were higher than the recommended value of 0.6 mg KOH/g oil for refined edible oils (FAO/WHO, 1999).

Physical and phytochemical composition

The physical and phytochemical compositions of the extracted crude oils in mg/g oil are presented in Table 2.

Physical composition

Results on the refractive indices of the extracted oils ranged from 1.4627±0.00 to 1.4695±0.00 for *A. hypogaea, C. cajan* and *Glycine max* respectively. *A. digitata* had a refractive index of 1.4640±0.00 which was slightly lower than the value of 1.4678±0.00 for *M. oleifera* and *P. curatellifolia* oils respectively. The refractive index for *M. oleifera* oil was higher than the value of 1.4559 (Adegbe et al., 2016) but very close to the value of 1.4668 (Garba et al., 2015) as compared to studies previously done by other researchers. In addition, the *A. digitata* refractive index of 1.4640±0.00 was similar to 1.498±0.002 (Oyeleke et al., 2012) and 1.5±0.0 (Osman, 2004) for *A. digitata* oil studies conducted in Nigeria and Saudi Arabia. Refractive indices of oils increase with either the increasing degree of unsaturation or increasing chain length of fatty acids in the triglycerides (Evans et al., 1974). The close values for the refractive indices of oils as presented in Table 2 probably suggest that the oils have either similar unsaturation or chain length. It was interesting to observe that the *A. hypogeae* and *A. digitata* refractive index values were within the recommended values of 1.460-1.465 (FAO/WHO, 1999) for *A. hypogaea* whereas the refractive indices for *P. curatellifolia* (1.4678±0.0), *C. cajan* (1.4695±0.0) *Glycine max* (1.4695±0.0) and *M. oleifera* (1.4678±0.0) were closely similar to the recommended value for crude *A. hypogaea* (FAO/WHO, 1999).

The calculated specific gravity for the crude oils ranged from 0.8650±0.00 to 0.9144±0.00 for *Glycine max* and *A. hypogaea* respectively. *G. max* and *C. cajan* had similar specific gravity values of 0.8848±0.0 and 0.8650±0.00 whereas *P. curatellifolia*, *A. digitata* and *M. oleifera* had specific gravity values of 0.8750±0.0, 0.8848±0.0 and 0.8891±0.0 respectively. When compared with findings obtained by other researchers, it was observed that *M. oleifera* had lower specific gravity value than the value of 0.9050 (Adegbe et al., 2012) but was within the range of 0.91±0.31 (Abiodun et al., 2012). On the other hand, *A. digitata* specific gravity value of 0.8848±0.0 was close to the value of 0.9±0.00 (Osman, 2004) but slightly lower than the value of 0.928±0.001 (Oyeleke et al., 2012) for studies conducted in Saudi Arabia and Nigeria. The specific gravity values for the crude oils were within the recommended standard values of 0.9-1.16 for edible oils (FAO/WHO, 2009) and 0.919-0.925 for soybean oils (FAO, 1995).

Phytochemical composition

Results showed that the phytate composition for the extracted crude oils, in mg/g, ranged from 44.52±0.40 to 240.47±5.24 for *A. hypogaea* and *C. cajan* respectively. Phytate content in *M. oleifera* (87.78±0.22) was low compared to *C. cajan* (240.47±5.24) and *G. max* (104.32±0.12) but higher than 65.25±0.05 for *P. curatellifolia* and closely similar to the value of 86.08±0.04 for *A. digitata* observed in this study. Phytic acid is an antinutritional factor that forms insoluble salts when mixed with food salts like phosphorus, calcium, iron magnesium and zinc making them unavailable for absorption into the blood system (Schlemmer et al., 2009). Phytate content in foodstuffs can be used in calculation of available phosphorus for absorption into the blood stream (Robert and Yudkin, 1999). Phytate content in *A. hypogaea* was high compared to the value of 4.18 mg/g oil obtained by other authors (Inuwa et al., 2011).

Oxalate content ranged from 75.41±0.40 to 632.56±4.90 mg/100 g for *A. hypogaea* and *C. cajan* respectively. Oxalate content for *A. digitata* was 210.08±17.80 mg/100 g which was high compared to *M. oleifera* (149.916±3.42 mg/100 g), *G. max* (116.04±6.34), *P. curatellifolia* 169.92(0.61) mg/100 g and *A. hypogaea* but lower than *C. cajan* obtained in this study. Oxalate content in *A. hypogaea* was higher than the value of 4.18 mg/g oil (Inuwa et al., 2011) when compared with findings from other researchers. *M. oleifera* oil registered a higher oxalate content compared to the value of 4.12±0.04 mg/g oil (Abiodun et al., 2012) reported in related studies.

Alkaloids content, in mg/g oil, ranged from 58.28±4.88 to 1005±1.0 mg/g for *M. oleifera* and *A. digitata* oil respectively. *P. curatellifolia* oil had alkaloid content of 102.65±1.89 mg/g which was lower than the values obtained in *A. digitata* (1005±1.0 mg/g), *G. max* (163.50±3.80) and *A. hypogaea* (323.60±23.84 mg/g) oil obtained in this study. Alkaloids contents in *G. max* and

Table 2. Physical and phytochemical properties of extracted oil.

Samples	Refractive index (25°C)	Specific gravity (25°C)	Phytate (mg/g)	Oxalate (mg/100 g)	Alkaloids (mg/g)
Moringa oleifera	1.4678±0.0[a]	0.8891±0.0[a]	87.78±0.22[a]	149.916±3.42[a]	58.28±4.88[a]
Parinari curatellifolia	1.4678±0.0[a]	0.8750±0.0[a]	65.25± 0.05[b]	169.92±0.61[b]	102.65±1.89[b]
Baobab (*Adansonia digitata*)	1.4640±0.0[a]	0.8848±0.0[a]	86.08± 0.04[c]	210.08±17.80[c]	1005±1.00[c]
Soybean (*Glycine max*)	1.4695±0.0[a]	0.8650±0.0[a]	104.32±0.12[d]	116.04±6.34[d]	163.50±3.80[d]
Pigeon pea (*Cajanus cajan*)	1.4695±0.0[a]	0.8652±0.0[a]	240.47±5.24[e]	632.56±4.90[e]	ND
Groundnut (*Arachis hypogeae*)	1.4627±0.0[a]	0.9144±0.0[a]	44.52± 0.40[f]	75.41±0.40[f]	323.60±23.84[e]

For each parameter, means with same superscript were not significantly different (P>0.05).

A. hypogeae were higher than the values of 2.5 and 3.3 mg/g (Mbagwu et al., 2011) reported in related studies by other authors.

On the other hand, flavonoids content in extracted crude oil was highest in *P. curatellifolia* (327.00±20.24 mg/g) compared to 79.24±1.55 mg/g for *A. digitata* observed in this study. *M. oleifera* oil has previously been reported to contain total flavonoids content of 18±0.01 mg/g oil (Ogbunugafor et al., 2011).

Conclusions

Results from this study have shown that there are differences in quality parameters in oils extracted from conventional and non-conventional sources. It has also been demonstrated that non-conventional sources of oil like *M. oleifera*, *P. curatellifolia* and *A. digitata* have the potential to become new sources of cheap vegetable oil which can be used by consumers. Results have further shown that oils from non-conventional sources have high oil yield values compared to conventional sources with exception of *C. cajan.* The low iodine and peroxide values of the conventional oils suggest that the oils have longer shelf life and are suitable for human consumption because of their saturation. It is therefore recommended that opportunities for extracting oils from non-conventional sources should be encouraged.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Abubakar S, Etim V, Bwai D, Afolayan M (2015). Nutraceutical evaluation of baobab (*Adansonia digitata L.)* seeds and physicochemical properties of its oil. Annals of Biological Sciences 3(2):13-19.

Abiodun OA, Adegbite JA, Omolola AO (2012). Chemical and physicochemical properties of Moringa flours and oil. Global Journal of Science Frontier Research Biological Sciences 12:5.

Adebowale OJ, Maliki K (2011). Effect of fermentation period on the chemical composition and functional properties of Pigeon pea (*Cajanus cajan*) seed flour. International Food Research Journal 18(4):1329-1333.

Adegbe AA, Larayetan RA, Omojuwa TJ (2016). Proximate analysis, physicochemical properties and chemical constituents characterization of *Moringa oleifera* (*Moringaceae*) seed oil using GC-MS analysis. American Journal of Chemistry 6(2):23-28.

Adejumo BA, Inaede SG, Adamu TS. (2013). Effect of moisture content on the yield and characteristics of oil from *Moringa oleifera* seeds. Academic Research International. www.savap.org.pk

Amadi BA, Lele KC, Duru MKC (2013). Extraction and characterization of vegetable oils from legume and palmae; using African Oil Bean (*Pentaclethra macrophylla*) and "Akwu Ojukwu" (*Elais guineensis*) respectively. American Journal of Biological and Life Science 1(1):7-10.

Anwar F, Rashid U (2007) physico-chemical characteristics of *Moringa oleifera* seeds and seed oil from a wild provenance of Pakistan. Pakistan Journal of Botany 39:1443-1453.

Anwar F, Ashraf M, Bhanger MI (2005). Interprovenance variation in the composition of Moringa oleifera oilseeds from Pakistan. Journal of American Oil Chemists' Society 82:45-51.

Association of Official Analytical Chemists (AOAC) (1996). Official methods of analysis. 18th edn. AOAC International, Arlington, VA.

Atasie VN, Akinhanmi TF, Ojiodu CC (2009). Proximate analysis and physico-chemical properties of groundnut (*Arachis hypogaea* L.). Pakistan Journal of Nutrition 8(2):194-197.

Basuny AM, Al-Marzouq A (2016). Biochemical studies on *Moringa oleifera* seed oil. Food Processing Technology 2(2):1-6.

Bremer B, Bremer K, Chase MW, Reveal JL, Soltis DE, Soltis PS, Stevens PF, Anderberg AA, Fay MF, Goldblatt P, Judd WS, Kallersjo M, Karehed J, Kron KA, Lundberg J, Nickrent DL, Olmstead RG, Oxelman B, Pires JC, Rodman JE, Rudall PJ, Savolainen V, Sytsma KJ, Van der Bank M, Wurdack K, Xiang IQY, Zmarzty S (2003). An update of the angiosperm phylogeny group classification for the orders and families of flowering plants. APGII. Botanical Journal of the Linnean Society 141:399-436.

Boham BA, Kocipai–Abyazan R (1974). Flavonoids and condensed tannins from leaves of Hawairan *vaccinum*

valiculatum and *V. calycinium*. Pacific Sciences 48:458-463.
Chinma CE, Igyor MA (2007). Micronutrients and anti- nutritional contents of selected tropical vegetables grown in Southern Nigeria. Nigerian Food Journal 25(1):111-116.
Choudhary RB, Pande PP (2000). Alternative solvent system for iodine value determination. Indian Journal of Chemical Technology 7:165-167.
Edogbanya PRO (2016). Composition of edible parts of *Adansonia digitata L.* obtained from Zaria, Kaduna state, Nigeria. Journal of Biology 1:1-6.
Egbuonu ACC, Aguguesi RG, Samuel O, Ojunkwu O, Onyenmeri F, Uzuegbu (2015). Some physicochemical properties of the petroleum ether-extracted watermelon (*Citrullus lanatus*) seed oil. Asian Journal of Scientific Research 8(4):519-525
Essien NM, Ofem OE, Bassey SC (2014). Comparative physical characterization, physio-chemical and fatty acid composition of some edible vegetable oils. Journal of Advances in Biology and Biotechnology 1(1):30-39.
Evans LD, List GR, Black LT (1974). Quality of oil from damaged soya beans. Journal of American Oil Chemists' Society 55:535-545.
Ezeagu IE (2005). Baobab (*Adansonia digitata* L.) seeds protein utilization in young albino rats I: Biochemical ingredients and performance characteristics. Animal Research International 2(1):240-245.
FAO/WHO (1999). Standard for named vegetable oils codex stan 210-1999. Codex Alimentarius Commission. Food and Agriculture Organisation of the United Nations. World Health Organisation, Rome:1-13
FAO/WHO (2009). Joint FAO/WHO Food Standard Programme Codex Alimentarius commission. Report of the 21st session of the Codex Alimentarius Committee on fats and oils. Kola Kinabalu, Malaysia, 16-20 February.
Foidl N, Makkar HPS, Becker K. (2001). The potential of *Moringa oleifera* for agricultural and industrial uses. In: Proceedings of the Workshop. What Development Potential for *Moringa oleifera*? Dar Es Salaam, October 20th – November 2nd, 2001.
Garba AA, Medugu DW, Gwaski, PA, Amusat RO (2015). Extraction and characterization of *Moringa oleifera* seed oil. Applied Research Journal 1(9):473-477.
Graham PH, Vance CP (2003). Legumes: importance and constraints to greater use. Plant Physiology 131:872-877.
Halvorsen JB, Mammel Jr. WC, Clements LD (1993). Density estimation of fatty acids and vegetable oils based on their fatty acid composition. Journal of American Oil Chemists' Society 70(9):875-880.
Igboeldi LC, Addy OH, Salami AI (1997). Effect of some processing techniques on the unti-nutrient content of baobab seeds (*Adansonia digitata*). Bioresearch Technology 59:29-31.
Idouraine A, Kohlhepp EA, Weber CW (1996). Nutrient constituents from eight lines of naked seed squash (*Cucurbita pepo L*.). Journal of Agriculture and Food Chemistry 44:721-724.
Ikemefuna CO, Amaechi NA (1992). The effect of processing methods on the chemical composition of baobab (*Adansonia digitata. L*) pulp and seed. Ecology of Food and Nutrition 29:199-205.
Inuwa HM, Aina VO, Gabi B, Aimola I, Toyin A (2011). Comparative determination of anti-nutritional factors in groundnut oil and palm oil. Advance Journal of Food Science and Technology 3(4):275-279.
Joshi A, Singhal PK, Bachheti RK (2012). Oil content variations and physco-chemical properties of *Jatropha curcus* seed oil collected from Kumaun region of Uttarakhad, India. International Journal of Chemical Sciences 10(4):1951-1958.
Kojima Y, Parcell J, Cain J (2016). A global demand analysis of vegetable oils for food and industrial use: A cross-country panel data analysis with spatial econometrics. In 2016 Annual Meeting, July 31 – August 2, Boston, Massachussets (No.235744). Agriculture and applied economics association. https://ageconsearch.umn.edu/record/235744/
Kumar BS, Shankar SR, Vasanthi RP, Vishnuvardhan KM, Purushothan M (2013). Comparative physico-chemical, proximate and mineral analysis on raw and roasted seeds of groundnut. Communications in Plant Sciences 3(3-4):25-29.
Lalas S, Tsaknis J (2002). Characterization of Moringa oleifera seed oil variety “Periyakulam 1”. Journal of Food Composition and Analysis 15:65-77.
Leone A, Spada A, Battezati A, Schiraldi A, Aristil J, Bertoli S (2016). *Moringa oleifera* seeds and oil: characteristics and uses for human health. International Journal of Molecular Sciences 17:2-14 www.mdpi.com/journal/ijms
Mielke T (2017). Global supply, demand and price outlook for vegetable oil in 2017/18. Global market research on oilseeds, oils and meals. www.globoilindia.com/2017mumbai_presentations/Thomas%20Mielke
Mousavi K, Shoeibi S, Ameri M (2012). Effects of storage conditions and PET packaging on quality of edible oils in Iran. Advances in Environmental Biology 6(2):694-701.
Mbagwu FN, Okafor VU, Ekeanyanwu J (2011). Phytochemical screening on four edible legumes (*Vigna subterranean*, *Glycine max*, *Arachis hypogaea* and *Vigna uniguiculata*) found in eastern Nigeria. African Journal of Plant Sciences 5(6):370-372.
Nadeem M, Imran M (2006). Promising features of *Moringa oleifera* oil: recent updates and perspectives. Lipids in Health and diseases 15:212. https://lipidworld.biomedcentral.com/track/epub/10.1186/s12944-016
Ndaba TK (2014). Characterization of oil extracted from *Parinari curatellifolia* (Hacha) nuts. MSc Thesis. University of Zimbabwe.
Ndabikunze BK, Mugasha AG, Chcimshama SAD, Tiisekwa BPM (2006). Nutritive value of selected forest/woodland edible fruits and nuts in Tanzania. Tanzania Journal of Agricultural Sciences 7(1):27-33.
Nkafamiya II, Maina HM, Osemeahon SA, Modobbo UU (2010). Percentage oil yield and physiochemical properties of groundnut species (*Arachis hypogeae*). African Journal of Food Sciences 4(7):418-421.
Nwosu CD, Ojimelukwe PC (1993). Improvement of the traditional method of ogiri production and identification of the microorganisms associated with the fermentation process. Plant Foods for Human Nutrition 43:267-272.
Obadoni BO, Ochuko PO (2001). Phytochemical studies and comparative efficacy of the crude extracts of some homestatic plants in Edo and Delta States of Nigeria. Global Journal of Pure and Applied Sciences 8:203-208.
Ogbunugafor HA, Eneh FU, Ozumba AN, Igwo-Ezikpe MN, Okpuzor J, Igwilo IO, Adenekan SO, Onyekwelu AO (2011) Physico-chemical and antioxidant properties of *Moringa oleifera* seed oil. Pakistan Journal of Nutrition 10(5):409-414.
Ogungbenle HN, Sanusi DS (2015). Extraction, physicochemical, phytosterols and fatty acid of *Celosia spicata* leaves. British Journal of Research 2(1):009-020.
Ogungbenle HN (2014). Sugar, physico chemical properties and fatty acid composition of velvet tarmarind pulp and oil. European Journal of Biotechnology and Bioscience 2(3):33-37.
Okene EO, Evbuomwan BO (2014). Solvent extraction and characteristics of oil from coconut seeds using alternative solvents. International Journal of Engineering and Technical Research 2(12):135-138. https://www.erpublication.org/published_paper/IJETR022982.pdf
Okorie SU, Nwachukwu CN (2014). Comparative evaluation of quality characteristics of oils extracted from some selected legumes and a cereal. Journal of Environmental Science, Toxicology and Food Technology 8(7):66-69.
Oladimeji AO, Bello MO (2011). Proximate analysis and fatty-acid profiles of mobola plum seed. Elixir Applied Chemistry 41:5942-5943.
Olawumi IA, Ojukwu M, Eboh B (2012). Comparative study on the physico-chemical properties of pigeon pea (*Cajanus cajan*) flour and protein isolate. International Journal of Agricultural and Food Science 2(4):121-126.
Osman MA (2004). Chemical and nutrient analysis of Baobab (*Adansonia digitata*) fruit and seed protein solubility. Plant Foods for Human Nutrition 59:29-33.
Oyeleke GO, Salam MA, Adetoro RO (2012). Some aspects of nutrient analysis of seed, pulp and oil of baobab (Adansonia digitata L.). International Journal of Environmental Science, Toxicology and Food Technology 1(4):32-35.
Preeti NK, Jood S, Goyal R (2007). Fatty acid composition and physico-chemical characteristics of cooking oils and their blends. Journal of

Dairying, Foods and Home Sciences 26(3/4):202-208.
Reddy NR, Sathe SK, Salunkhe DK (1982). Phytate in legumes and cereals. Advance Food Research 28:1-92.
Robert HA, Yudkin J (1999). Effect of phytate and other dietary factors and bone calcification in the rat. British Journal of Nutrition 15:467.
Rusníková L, Straková E, Suchý P (2013). Assessment of oils of selected legumes and oil plants with regard to animal nutrition. Acta Veterinaria Brno 82:283-288.
Sarwar MF, Sarwar MH, Sarwar M, Qadri NA, Moghal S (2013). The role of oilseeds in nutritional health: A critical review. Journal of Cereals and oilseeds 4(8):97-100.
Schlemmer U, Frølich W, Prieto RM, Grases F (2009). Phytate in foods and significance for humans: Food sources, intake, processing, bioavailability, protective role and analysis. Molecular Nutrition and Food Research 53:330-375.
Siulapwa N, Mwambugu A (2014). Nutritional value of differently processed soybean seeds. International Journal of Research in Agriculture and Food Sciences 2(6):8-16
Siyanbola TO, Edobor-Osoh A, Ajanaku CO, Akinsiku AA, Adedapo EA, Aladesuyi O, Olarenwaju IO, Jokotagba OA (2015). Nutritional and physico-chemical evaluation of *Moringa oleifera* seedlings and oil. Journal of Advance Research in Applied Chemistry 1(1):1-5.
Stevenson DG, Eller FJ, Wang L, Jane JL, Inglett GE (2007). Oil and Tocopherol content and composition of pumpkin seed oil in 12 cultivars. Journal of Agricultural and Food Chemistry 55:4005-4013.
Temu A, Rudebjer P, Yaye AD, Ochola AO (2016). Curriculum guide on neglected and underutilized species: Combating hunger and malnutrition with novel species. African network for agriculture, agroforestry and natural resource education (ANAFE), Nairobi, Kenya and Bioversity International, Rome, Italy. http://www.nuscommunity.org/fileadmin/templates/nuscommunity.org/upload/documents/Publ