MALAYSIAN JOURNAL OF APPLIED SCIENCES 2020, VOL 5 (2): 69-77
E-ISSN:0127-9246 (ONLINE)
http://dx.doi.org/10.37231/myjas.2020.5.2.236
https://journal.unisza.edu.my/myjas

PENERBIT
Universiti Sultan Zainal Abidin

MALAYSIAN JOURNAL OF APPLIED SCIENCES
eISSN:0127-9246

ORIGINAL ARTICLE

Comparative Study of Physicochemical Properties of *Tithonia diversifolia* and Sunflower Seed Oils

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Received: 18/03/2020, Accepted: 26/10/2020, Published: 31/10/2020

Abstract

This study investigates the physico-chemical properties of *Tithonia diversifolia* seed and oil using standard analytical methods and then compared the results with Sunflower oil. The results showed that *Tithonia diversifolia* seed contained 5.80% moisture, 18.83% crude protein, 30.40% crude fat, 17.85% crude fibre, 4.30% ash and 22.82% carbohydrate. The content of magnesium, copper, iron, zinc and calcium were 3930, 168, 277, 2091 and 432 mg/kg, respectively. Iodine value for *T. diversifolia* and Sunflower oils, respectively were 109.00 and 145.67 g iodine/kg; saponification values, 212.61 and 188.63 mg KOH/g; ester values, 184.15 and 206.86 mg KOH/g; peroxide values 4.0 and 5.87 meq peroxide/kg; acid values, 5.76 and 4.48 mg KOH / g; % unsaponifiable matter, 0.83 and 1.22 %; and total phenol content, 118.63 and 108.75 µg/g. Others include, specific gravity, 0.937 and 0.920; surface tension 0.042 and 0.051 N/m; viscosity 42.50 and 30.50 cSt; and smoke point, 215 and 245 ^{0}C. The study revealed that *Tithonia diversifolia* seed oil content and physicochemical parameters are comparable with those of Sunflower oil. Hence the oil could be used as raw materials for industrial processes, biodiesel production and a good source of dietary antioxidant which could complement or replace some conventional oils.

Keywords: Elemental análisis, oil seed, proximate, saponification, *tithonia diversifolia*

Introduction

Over the years, there has been a spectacular increase in the World demand for both oils and oil meals with attending up-trend in prices (Mielke, 1988). The significance of oilseeds economically, nationally and technologically is enormous and cannot be over emphasized. Among its uses are in edible and non edible applications such as cooking, lubrication, body massage, grease and so on.

In the same vein, most developing countries in the world today face the problem of inadequate protein intake by large section of their population. For example in west Africa, most traditional foods are carbohydrate based foods such as cassava, maize, yams, cocoyam and rice, supplemented with plantains and beans and thus are lacking in other nutrients particularly proteins. As a result of this, attention has been shifted to alternative source of proteins particularly among the oil seeds, legumes and lesser known plant sources (Onimawo and Adukwu, 2003).

Sunflower is a major source of vegetable oil in the world most especially in the Western countries. Two types of Sunflower are grown (those cultivated for oilseed production and those used as ornamental plant to beautify surrounding). Seed of the oilseed varieties contain between 38 to 50 % oil and about 20 % protein. Non-oilseed Sunflower also referred to as confectionery Sunflower has relatively low oil content and the seeds are also very light (Lawson, 1995).

World production of Sunflower is increasing steadily due to increase in its acceptability. Domestic use and export of non-oilseed Sunflower has also increased. The American Indians used Sunflowers as a foodstuff before the cultivation of corn. Sunflower has also been reported to be useful as a medicinal plant, source of dye, oil for ceremonial body painting and pottery. It is also used in food industry as dressings oil for example in salad, seasoning, frying and other preparations (Asami *et al.*, 2003).

Tithonia Desfex Juss. is a small genus of 12 taxa in the family Asteraceae having its centre of origin in central America and Mexico from where it was introduced to other parts of the world. It is a member of the same tribe Heliantheae, as the Sunflower (Robinson, 1981) which explains its common name, Mexican Sunflower. The genus is represented in Nigeria by two species, *T. rotundifolia* (Mill.) and *T. diversifolia* (Hemsl.).

Tithonia rotundifolia is an annual herbaceous plant with erect ascending stem which can reach a height of 5m depending on ecological situation. The inflorescence is a capitulum which produces 8-13 ray floret and 65 – 90 disk florets. The potential for massive seed production is closely tied to the number of disk florets as these give rise to seeds. A major characteristics of invasive plants is their reproduction success especially with respect to seed production. *T. rotundifolia* is no exception as individual plants can produce over 17, 000 seeds (Muoghalu and Chuba, 2005).

This reproductive aggressiveness, which is usually viewed in a negative sense from conservation perspective, may have a useful side to it. The ease with which *T. rotundifolia* seeds germinate, the rapid growth rate (Adebowale and Olorode, 2005) and close phytogenetic relationship with Sunflower (known for its commercially viable oil production) necessitates an investigation into the oil chemistry quality and quantity of this plant. It is a known fact in phyto-medicine that closely related taxa, because of their shared evolutionary history, also share similar biochemistry.

Tithonia diversifolia was chosen for this study because of its similarity to Sunflower which oil is the major edible oil in the western countries. To the best of our knowledge, there is paucity of literature, or little or no work done on the physical and chemical properties of *Tithonia diversifolia* oil. The physico-chemical properties and proximate composition of a food source determine not only average nutrient content, but also find alternative uses for such food materials. This study was therefore carried out to investigate the proximate composition and the physico–chemical properties of *Tithonia diversifolia* oil in comparison with that of Sunflower oil.

Materials and Methods

Sample Preparation

The fruits were collected from the plant located along the road side on the Ilesha –Ife Express way, in Nigeria, in the dry month of November – December 2005. The dry fruits were crushed and spit open giving way for smaller seeds with a dark brown, hard covering . The seeds were separated from the fruit shafts and dried further. The dried seeds were crushed using a manual grinding machine. The white endosperm was separated from the outer coat of the seed. The separated endosperm was stored in a polythene bag and kept in a refrigerated until needed for analysis.

Proximate composition of *Tithonia diversifolia* seed flour

The seed of *Tithonia diversifolia* was analyzed for moisture, ash, fibre and protein content using the AOAC (2000) procedure. Crude protein (N x 6.25). The oil content was determined by soxhlet extraction method while carbohydrate was determined by difference.

Physico-chemical analysis of oil

The oils content of the samples were extracted with hexane using soxhlet extraction method and the chemical parameters of the extracted oils were analysed using Association of Official Analytical Chemists' methods (AOAC 936.16; AOAC 920.158 and AOAC 936.15 for acid value, iodine value and saponification value respectively).

The physical parameters such as viscosity were determined using the Ostward kinematic viscometer (model PSL ASTM – IPUviscometer tube, England). The refractive index was determined using the Abbey refractometer (model CARL ZEISS 114484, Germany) while the specific gravity was obtained using a 10 mL standard specific gravity bottle (model nom. 10mL BS733, Jaytec. U.K) at 25 ± 2^0C.

Determination of total phenol

Total phenol was determined colorimetrically using Folin-Ciocalteau reagent according to method of Singleton *et al.,* (1999). The oil (1.0 mL) was dissolved in 10 mL methanol, then 1.0mL of the solution was put in different screw cap test tubes; 0.1 mL of Folin-Ciocalteau reagent and 2.5 mL of sodium carbonate solution (20 %) were added, mixed and kept in the dark for 90 minutes. Absorbance was measured at 725 nm using UV-Visible spectrophotometer (Pye Unicam Ltd, UK). Gallic acid was taken as the standard and the results were expressed as mg gallic acid equivalent / g (mg GAE / g).

Elemental analysis

The oil samples were digested for mineral analysis as previously described (Falade *et al*. 2005) with some modifications. Sample (0.5000 g) was weighed into 100 mL beaker and 10 mL concentrated HNO_3 was added and left overnight. The mixture was heated at low heat on a hot plate until the brown fume of NO_2 ceased. $HClO_3$ (4.0 mL) was added and the heating continued for about 30 min. 10 mL of H_2O_2 was added slowly and heating continued until the solution turned colorless.

The digested sample was later transferred into a 50 mL standard flask and diluted to mark with double distilled water. The mineral content was determined using Atomic Absorption Spectrophotometer (Varian Spectr AA 220, Varian Ltd., Surrey, UK). Spiking method was used for quality control of the mineral analysis. Tithonia sample (0.5000g) was weighed in triplicate and each was spiked with 60, 60, 8, 20 and 8 mg/L of Mg, Ca, Zn, Fe and Cu respectively. The spiked samples were digested and analyzed following same procedure for mineral analysis as described above. All parameters were determined in triplicates and standard errors were calculated.

Statistical analysis

All analyses were carried out in triplicate determinations and the results were presented as mean and standard deviation of triplicate analysis. Student T-test was used to test the significant difference in the results between the samples.

Results and Discussion

Chemical composition of seed

The results of the proximate and mineral compositions of the seed of T. *diversifolia* are presented in Table 1. The moisture content was 5.80%. The value agreed with reported values for some conventional and non-conventional oilseeds like Soybean (4.48%), *Irvingia gabonensis* (4.73 %) and *Terminal catappa* (4.22%) (Akanni *et al*., 2005). The low moisture content (5.80%) of Tithonia seeds is an advantage of high shelves-life and improves quality since a mature seed has lower moisture than immature ones.

The oil content was 30.40%, indicating that the seed can also be classified as oilseeds since the value of oil obtained is greater than 18 – 21.60 and 22.35% reported for Soybean oil (Oguntunde and Ajayi, 1994; Akanni et al., 2005). It also compete favourably in oil content with 49.49% reported for *Heavea brasiliensis* 48.1% for cashew nut ; Sunflower seed oil (35 – 45 %); Palm kernel and Groundnut seeds oil (45- 50%) (Fetuga *et al.*, 1974).

Even though Tithonia is a weed whose economic potential has not been intensively explored, but with the high oil value (30.40%) recorded, the seed could be positioned in the same class of importance and application as conventional Sunflower oil. However, its toxicological properties needs to be established before it can be deem fit as edible oil.

The protein content (18. 83%) of the oil agreed closely with the range 21- 23% reported for legumes (Adewusi and Falade, 1996). Thus the seed and its oil can be a promising source of dietary protein if the potential is judiciously harnessed.

The crude fibre content (17.85%) reported for Tithonia seed is greater than 5.97 and 8.26% reported for soybean and palm kernel seeds, conventional seeds (Akanni *et al.*, 2005) but closer to 14.5- 16.7% reported for Sunflower seed (Richard, 1986). It has been reported that fibre reduces glycemic index, reduces blood cholesterol, prevent cancer and lower the risk of heart disease (Lawson, 1995).

The percentage ash content was 4.30%, this value is greater than 3.2 and 3.1% reported for sesame and Sunflower seeds, respectively (Richard, 1986). It however agreed with 4.8% reported for *T. bellirica* but lower than 5.7% of *T. catappa* (Akanni et al., 2005). The difference in these values may be attributed to the differences in the mineral composition of the soil as plants or seeds derive their minerals from the adsorption of dissolved substances from the soil. *T. diversifolia* plant and its seed could therefore been seen as a potential source of essential minerals for both man and animals. The value (22. 82%) obtained for the carbohydrate is quite lower than 35.22% reported for soybean (Oguntunde and Ajayi 1994). The values obtained for the minerals in the seed of this plant tend to make it a good mineral source compare with other seed earlier reported. For example, the calcium (2091mg/kg) and iron (277mg/kg) levels fall within the range reported for some conventional and non-conventional oil seeds whereas the values rocorded for magnesium, zinc and copper were higher (Akanni *et al*., 2005).

The abundance of these elements may be attributed to their wide distribution in the soil. For example, calcium and magnesium are constituents of many silicates and carbonate minerals in the earth. These minerals form component of soil during soil formation and found their way into the plant by the root absorption. Generally, the minerals play vital role in physiologic and metabolic process in the body. For instance, calcium and magnesium play a vital role in bone formation while magnesium participate as enzyme activators and assists in the transmission of various signals especially during the contractor of cardiac muscle resulting in heart beat (Akanni *et al*., 2005). Iron is an important component of blood and enzyme involved in electron transfer.

Table 1: Proximate Composition (%) and Mineral content (mg/kg) of *Tithonia diversifolia* Seed

Parameter	***Tithonia diversifolia* Seed**
Moisture	5.80 ± 0.10
Crude protein	18.83 ± 0.32
Crude fibre	17.85 ± 0.46
Ash	4.30 ± 0.27
Oil	30.40 ± 1.90
Carbohydrate	22.82 ± 1.28
Mineral	
Cu	168 ± 14
Fe	277 ± 32
Mg	3930 ± 89
Zn	432 ± 20
Ca	2091 ± 26

Mean ± SD = mean and standard deviation of triplícate analysis

Physicochemical properties of oils

The chemical properties of the oils are presented in Table 2. The iodine value which is a measure of degree of unsaturation of oil was 145.67 and 109.00 g iodine/100g oil for Sunflower and Tithonia oil respectively. The value obtained for Tithonia oil is lower than that of Sunflower oil (a conventional oil) but compared favourably with that of groundnut oil (109.3 g iodine/100g oil) (Falade *et al*., 2008).

Iodine value is an important parameter in deciding if oils could be used either for domestic or industrial purposes. For instance, Palm kernel oil has a very low iodine value (14-20) (NIS, 1992). This is one of the reasons why it is commonly used for domestic purposes such as cooking and frying. Oils rich in unsaturated fatty acids have been reported to reduce heart diseases associated with cholesterol (Lawson, 1995). It may therefore be proper to suggest that the Tithonia oil investigated in this study should have more nutritional purposes than industrial applications. High iodine values also have its own disadvantages; for instance, the oil will be more susceptible to oxidative deterioration thereby making them difficult to store (Falade *et al*., 2005).

Table 2: Chemical properties of Sunflower and Tithonia seed oils

Characteristics	Sunflower Oil	Tithonia Oil
Ether extract*(%)	ND	30.40 ± 1.90
Iodine value (g iodine/100 g oil)	145.67 ± 1.15^{a}	109. 00 ± 1.10^{b}
Acid value (mg KOH / g oil)	4.48 ± 0.00^{b}	5.76 ± 0.13^{a}
Peroxide value (meq / kg)	4.00 ± 0.00^{b}	5.87 ± 0.23^{a}
Saponification value(mgKOH/g)	188.6 ± 2.00^{b}	212.62 ± 0.98^{a}
% Unsaponifiable matter	1.22 ± 0.03^{a}	0.83 ± 0.05^{b}
Ester Value	184.15 ± 2.02^{b}	206.86 ± 0.79^{a}
% FFA (as oleic)	2.25 ± 0.00^{b}	2.89 ± 0.06^{a}
Total Phenol (µg / g)	108.75 ± 5.75^{b}	174.4 ± 16.8^{a}
Colour	Bright yellow	Bright yellow
Odour	Sweet smell	Sweet smell
State at room temperature.	Liquid	Liquid

*the values were expressed on dry weight basis, ND = not determined
Mean ±SD; Mean and standard deviation of triplicate analysis
Values with different superscript along the row were significantly different at P ≤ 0.05

The acid value and percentage fatty acid are used as indicators or otherwise of oil suitability for used in the industries (Akubugwo and Ugbogu, 2007). The acid value obtained in this study are 4.48 and 5.67 mg KOH/g oil for Sunflower and Tithonia oils respectively, and fall within 1–6 mg KOH/g oil proposed for vegetable oils (Falade *et al*, 2008). Free fatty acids provide information on the status of vegetable oils. It is well known that free fatty acids are more susceptible to lipid oxidation leading to reduced smoke point, rancidity and production of off-odour compared to intact fatty acids in the triglyceride (FAO/WHO, 1993). The percentage free fatty acids are 2.25 and 2.89 % for Sunflower and Tithonia oils respectively. Although these values are higher than 0.4 % reported for groundnut oil, they are better than the range of 5.1 to 7.6 % reported for Acacia oils (Falade *et al*., 2008).

The peroxide value like acid value provides information on the quality of the vegetable oil as well as its susceptibility or not to lipid oxidation. The higher the peroxide value, the higher the oil susceptibility to lipid oxidation. The peroxide values obtained in this work are 4.0 and 5.87 meq/kg for Sunflower and Tithonia oils respectively. For oils to have acceptable storage stability, its peroxide value should be less than five (Rudan *et al*., 1999). Since Tithonia oil peroxide value was higher than five, the oil could be prone to lipid oxidation unless it is refined or protected with antioxidants. However, the value is still within the range reported for beniseed oil but lower than that of olive oil (20 meq/kg) and slightly lower than some of edible oils (Onimawo and Adukwu 2003).

The saponification value provided information on the suitability or otherwise of vegetable oil for use in soap making. The saponification values obtained are188.63 and 212.62 mg KOH/g oil for Sunflower and Tithonia oils respectively. The saponification value obtained for Tithonia oil is greater than that of some conventional oils. For instance, it is greater than 185 – 195 and 195 – 205 mg KOH/g reported for groundnut and palm oil, and also in close agreement to the range 245 – 255 mg/g reported for palm kernel oil (Onimawo and Adukwu 2003).

The high saponification value of the Tithonia oil suggest its use as an alternative source of raw materials to the conventional oils in soap, paint and adhesive industries. The unsaponifiable matter of the oil samples are 1.22 and 0.83 % for Sunflower and Tithonia oils respectively. Both values are higher than 0.6 % reported for groundnut oil but lower than 1.0 % reported for Acacia oil (Falade *et al.*, 2008). This parameter has been reported not to have any effect on the quality of biodiesel obtained from vegetable oils (Yuan et al., 2004), but will definitely reduce the quality of soap. It will be recalled that unsaponifiable matter provides information on the purity of oil, and its presence in oil indicates the presence of some or all the following compounds in the oil; sterols, vitamins, gum, lecithin and some hydrocarbons.

The total phenol content of the oil samples are 108.8 and 174.4 µg/g for Sunflower and Tithonia oils respectively. The higher value reported for Tithonia oil suggest more stability to oxidation of the oil compared with the Sunflower oil because of its higher polyphenol content. Phenolic compounds have been reported to contribute about 30 % to oil stability (Aparicio *et al.*, 2001). The result also indicates that Tithonia oil will be better source of dietary antioxidant compared to Sunflower oil.

The physical properties of the oils are presented in Table 3. The surface tension of Tithonia oil (0.042 N/m) was lower than that of Sunflower oil (0.051 N/m). The value obtained for both oils was lower than that of water (0.07120 N/m) (Kirk, 1994), hence both oils could be used as water surface retardant in the desert region thereby preventing loss of water due to harsh weather condition of the desert. Also, the higher surface tension of Tithonia oil may be due to the presence of low percentage of gumming substances in the oil. Oil with low surface tension may be difficult to inject as it can cause a delay in the atomization and ignition processes in the ignition engine (Ryan *et al*., 1984). Thus Tithonia oil possess the potential to be used as diesel or petrol oil in ignition engine provided other physical properties of fuel are satisfied.

Table 3: Physical properties of Sunflower and Tithonia seed oils

Characteristics	Sunflower Oil	Tithonia Oil
Surface tension N/m	0.051 ± 0.00	0.042 ± 0.00
Specific gravity	0.920 ± 0.01	0.937 ± 2.02
Viscosity (cSt)	42.5 ± 0.05[a]	30.5 ± 0.05[b]
Smoke point ^{0}C	215 ± 1.00[b]	245 ± 2.00[a]

Mean ±SD; Mean and standard deviation of triplicate analysis
Values with different superscript along the row were significantly different at P ≤ 0.05

The specific gravity of Tithonia oil (0.937) is higher than that of Sunflower oil (0.920) (Table 3). This implies that the molecular weight of Tithonia seed oil is higher than that of Sunflower seed oil.In the opposite, viscosity of Tithonia oil (30.500 cSt) is lower than that of Sunflower oil (42.500 cSt). However, the viscosity value reported for Tithonia oil is lower compared to that reported for some conventional oils such as soybean oil (31 cSt) and cotton seed oil (36 cSt) at the same temperature (30 0C) (Kammann *et al.*, 1985). The specific gravity and viscosity of oils play important role in deciding the use of the oils for either industrial or domestic purpose. For instance, if the oil is too dense and highly viscous, then it may not be suitable for frying or baking since it may stick to the fried material and produces its taste rather than the desired taste of the fried material. However, the same oil may find application in lubricating industry. The low viscosity obtained for both Tithonia and Sunflower oils in this study is a good advantage for their use as biodiesel because oils or fuels with low viscosity would have a high degree of atomization resulting in a shorter ignition delay (Ryan *et al*., 1984). Smoke point refers to the point at which a cooking fat or oil breaks down when heated. The high smoke point value recorded for Tithonia oil (245.000 0C) compared with Sunflower oil smoke point (215.000 0C) suggest that Tithonia oil will be more suitable for use as frying oil than Sunflower oil provided other toxicological studies are carried out on the oil to established its safety for food. The refractive index obtained for Tithonia oil in this study is 1.4717, this value is higher than the values reported for soybean (1.466 - 1.470), and palm kernel oil (1.449 - 1.451) at room temperature (NIS, 1992). Since the Tithonia oil has higher refractive index than water (1.330) at room temperature, it may therefore be used as a better refractive agent in optical devices than wáter. Table 4 presents the effect of Temperature on the viscosity and specific gravity of the oils. The viscosity and specific gravity of the oils decreased with increase in temperature. The rate at which the oils lost their viscosity with increasing temperature calls for their use as lubricants in heavy duty machines where large amount of energy is produced.

Table 4: Effect of Temperature on Viscosity and Specific Gravity of Sunflower and Tithonia Oil

Temperature ^{0}C	Sunflower Oil	Tithonia Oil
	Viscosity (cSt)	
30	42.50 ± 0.05[a]	30.50 ± 0.05[b]
40	36.23 ± 0.28[a]	29.43 ± 0.04[b]
50	35.69 ± 0.03[a]	28.26 ± 0.2[b]
60	30.33 ± 0.02[a]	23.36 ± 0.04[b]
70	28.31 ± 0.1[a]	23.13 ± 0.07[b]
80	25.44 ± 0.07[a]	20.7 ± 0.17[b]
	Specific gravity	
30	0.920 ± 0.01	0.937 ± 2.02
40	0.902 ± 0.01	0.933 ± 0.00
50	0.873 ± 0.00	0.931 ± 0.00
60	0.816 ± 0.01	0.930 ± 0.00
70	0.783 ± 0.00	0.929 ± 0.00
80	0.712 ± 0.00	0.886 ± 0.00

Mean ±SD; Mean and standard deviation of triplicate analysis
Values along the row with different superscript were significantly different at P ≤ 0.05)

Conclusions

The result of this study showed that the seed of *Tithonia diversifolia* is a potential source of protein, mineral and oil which can supplement the already existing conventional seeds. The physico-chemical properties of the Tithonia oil examined in this work also revealed that the oil possesses interesting properties over Sunflower oil, and could be a good source of edible oil compared with Sunflower oil and other conventional oil if the potential of the oil is properly tapped. The high total phenol content of the oil makes it a better source of dietary antioxidant compared to Sunflower oil.

The high smoke point suggests that Tithonia oil will be more suitable for use as frying oil than Sunflower oil. The high iodine value of Tithonia oil makes it a potential drying oil and a solvent in paint, adhesive, perfumes and other related industries. High saponification value of Tithonia oil makes it a potential raw material for soap industry. Its low viscosity value over Sunflower oil is an advantage for its use as biodiesel because of high degree of atomization and shorter ignition delay. Therefore, the cultivation of Tithonia as economic plants should be encouraged and its seed oil fully explored for different applications to reduce the prices and over-dependence on conventional oils which are gradually getting out of the reach of the average people.

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How to cite this paper: I. O. Otemuyiwa, A. S Adekunle, and J.F. Adegbite, O. S. Falade (2020). Comparative Study of Physicochemical Properties of Tithonia diversifolia and Sunflower Seed Oils. *Malaysian Journal of Applied Sciences, 5*(2), 69-77.