



Physicochemical Properties of Pumpkin Seed Oil Relevant to Bio-diesel Production and other Industrial Applications

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Abstract: Physicochemical properties of vegetable oil are necessary in judging the suitability of oil for a particular application. These properties equally indicate the storability of vegetable oil under different packaging/environmental conditions. Oil was extracted from pumpkin seed using Soxhlet method, and physicochemical properties of the extracted oil were investigated for the effect of variety factor at three replications. Results were analyzed using one-way ANOVA at 5% level of probability. The oil content, acid value, saponification value, iodine value, specific gravity, oil viscosity, heating value and refractive index were 55.8%, 12.6mgKOH/g, 184.0mgKOH/g, 16.0gI₂/100g, 0.933, 45.0mm²/sec, 40.5MJ/kg and 1.463 respectively in *c. maxima* variety. Correspondingly, in *c. pepo*, these values were 52.8%, 62.6mgKOH/g, 187.0mgKOH/g, 15.8gI₂/100g, 0.9280, 44.7mm²/sec, 40.4MJ/kg and 1.461 respectively. Pumpkin seed oil is suitable for biodiesel, and soap production; however, it has no potential for ink and paint production.

Keywords: seed oil, variety, cucurbitaceae, pumpkin, Nigeria

I. Introduction

Plants of the cucurbitaceae family generally grow in the tropical, subtropical, arid and temperate climates of the world [1]. A wide range of varieties were reported some of which include *cucurbitaceae argysperma*, *c. filicifolia*, *c. foetidissima*, *c. maxima*, *c. mixta*, *c. moschata*, and *c. pepo* [2]. In West Africa, pumpkins are planted in the months of April to June the plant covers the soil surface within 4 – 6 weeks [1], and yields up to 500kg/m³ or more depending on the variety, production system, weed competition, plant diseases and climatic circumstance, [3]. Pumpkins have been cultivated for various reasons ranging from nutritional to medicinal purposes [5]; nutritionally, pumpkin seed kernels contain moderate concentrations of minerals especially phosphorus, magnesium, and potassium [6]. Medicinally, its effects were reported significant on helminthic e.g. *ascaris* [7], on breast, and lung cancers [4], in lowering blood's cholesterol level, and in enhancing the immune response in human beings [8]. Pumpkin seed oil has been extracted in Australia, Slovenia, and in Hungary [9] with variations in the range of the oil content. For example, oil content ranging from 34.5 to 43.6% was reported in eight lines of *cucurbita pepo* [5], 10.9 to 30.9 for *cucurbita maxima* [2], 27.83% for *cucurbitaceae maxima* [6], 50% for gourds and 44 – 54% for *cucurbitaceae* cultivated in Cameroun [10]. Researchers employed different methods in the extraction of oil from agricultural materials including (i) mechanical expression, (ii) solvent extraction (iii) A combination of mechanical expression and solvent extraction methods [11].

Solvent extraction method was satisfactorily employed in processing oil from seeds of low oil content such as soybeans, rice bran, mango kernels etc. [12]. Oil extraction methods and factors affecting their yield have been studied in plant and animal materials as reported by [13], [14] and [15].

Researchers such as [16], [15] and [17] investigated vegetable oil properties such as oil content, acid, iodine and saponification values, density and relative density, oil viscosity and heating value for a wide range of agricultural materials on beniseed, castor and rubber seed oils respectively. Some of the oil properties are important in judging the suitability of seed oil for particular applications [18]. For instance, the suitability of biodiesel fuel can be predicted from saponification and iodine values, density, specific gravity and the heating value of parent vegetable oil as observed by [16], [19] and [17].

Table 1; Physicochemical Properties of Seed Oils as Found in Literatures

Oil source/ Seed	OC %	AV mgKOH/g	SV mgKOH/g	IV gI ₂ /100g	SG dimensionless	RI dimensionless	V mm ² /s	HV MJ/kg	FFA %	Reference/ source
Moringa	40.39	NR	186.67	69.45	NR	1.4608	NR	NR	0.40	[35]
<i>C. pepo</i>	41.59	0.39	190.69	104.36	0.915	1.4662	93.65cp	NR	0.39	[36]
Cashew nut	49.1	10.7	137.0	41.3	0.962	1.458	56.0cp	NR	6.1	[31]
Fluted pumpkin	NR	7.59	179.02	85.12	0.926	NR	NR	NR	NR	[34]
Black beniseed	NR	NR	158.04	106.26	NR	NR	33.2	41.1	0.73	[16]
<i>C. maxima</i>	43.69	0.53	185.20	105.12	0.913	1.4656	48.09	NR	0.27	[6]
Agusi	30.0	40.0	189.5	104.4	0.874	1.4670	NR	NR	NR	[27]
Desert melon	28.0	2.5	182.1	124.0	0.954	1.468	NR	NR	NR	[27]
Rubber seed	68.17	13.46	28.07	NR	NR	585.41	NR	0.5854	4.11	[17]

NR= Not reported, OC = oil content, AV = acid value, SV = saponification value, IV = iodine value, V = oil viscosity, HV =heating value, FFA =free fatty acid, cp =centipore

Recently, researches in to the use of transesterified oils in automotive engines have yielded positive results, though the viscosity values of biodiesels were higher than that of the fossil diesel [20]. Reference [21] investigated the flow properties of biodiesel fuel produced from unrefined vegetable oils over a range of temperatures; result indicated reduction in fuel viscosity of up to 71% or more with increase in temperature from 15 to 100°C. Reference [22] compiled and published biodiesel standards including test methods, maximum and minimum limits and units of biodiesel properties. Heating value, an important fuel property which indicates the energy content of oil have been estimated from vegetable oil properties such as acid and saponification values as reported by [16] and [17] in their works on beniseed and Malaysian rubber seed oil respectively. Reference [23] evaluated sunflower, safflower, and rapeseed oils as possible sources of liquid fuels. Findings indicated that the energy content of these oils was up to 94 to 95% of the energy content of fossil diesel.

III. Materials and Methods

Pumpkin fruits were bought from a local market in Mayo-Nguli, Maiha local government area of Adamawa state, (located at: Latitude $10^{\circ}.15^1\text{N}$ and Longitude $13^{\circ}.16^1\text{E}$). The pumpkin fruits were cut and the seeds extracted manually from pulps. It was sun dried for two (2) weeks until it was dry at RH of 31.75% and mean daily temperature of 33.25°C . The pumpkin seeds were cleaned manually, which involved removing the immature/ broken seeds, foreign materials, and the powdered pulp. Oil was extracted from pumpkin seed using Soxhlet method in accordance with the procedures of [24] using the following materials: boiling flask, desiccators, petroleum ether and electric oven. The oil content of pumpkin seeds was calculated using this expression in equation (1) in accordance with [13].

$$\% \text{ Oil} = \left(\frac{w_2 - w_1}{w} \right) \times 100 \quad (1)$$

Where;

w = weight of sample, w_1 = weight of beaker with glass ball, w_2 = weight of beaker with glass ball and oil, $w_2 - w_1$ = weight of oil.

Acid value which is a measure of the free fatty acid present in fat/oil [18], for pumpkin seed oil, it was determined using diethyl ether, alcohol, phenolphthalein solution, sodium hydroxide, and pipette in accordance with the procedures used and reported by [14]. The acid value was computed using equation (2).

$$\text{Acid value} = \frac{\text{Titre (ml)} \times 5.61}{\text{weight of oil sample used}} \quad (2)$$

Saponification value which is the measure of mean molecular weight of fatty acid present in oil was determined for pumpkin seed oil using: conical flask, alcoholic potassium hydroxide, reflux condenser, phenolphthalein solution and 0.5M hydrochloric acid in accordance with the procedures of [24], and calculated using equation (3).

$$\text{Saponification value} = \frac{(b-a) \times 28.05}{\text{weight of sample}} \quad (3)$$

Where a , and b are the volumes of titration and blank (ml) used in the experiment.

Iodine value which is the measure of the unsaturation in oil [25], for pumpkin seed oil, it was determined using the following materials: carbon tetrachloride, Wiji's solution, potassium iodide solution and 0.1M thiosulphate solution using the procedures reported by [24], and was computed using equation (4).

$$\text{Iodine value} = \frac{(b-a) \times 1.269}{\text{weight of sample}} \quad (4)$$

Where a , and b are the volume of titration and blank used in the experiment.

Heating value, which is the energy content of oil, was estimated from iodine and saponification values of the pumpkin seed oil in accordance with [16] and calculated using equation (5).

$$H_{\mu} = 47645 - 4.187IV - 38.31SV \quad (5)$$

Where H_{μ} = heating value of oil (MJ/kg), IV = iodine value ($\text{gI}_2/100\text{g}$), SV = Saponification value (mgKOH/g)

Refractive index was calculated in terms of the iodine, saponification and acid values of pumpkin seed oil using the expression by [24] as stated in equation (6).

$$RI = 1.4643 - 0.0000665 \frac{0.0096AV}{SV + 0.000117IV} \quad (6)$$

Where IV = iodine value (gI₂/100g), SV = Saponification value (mgKOH/g), AV= acid value (mgKOH/g).

Specific gravity, which is an indicator of the molecular weight of the substance and its degree of unsaturation [26] for pumpkin seed oil was, determined using a pycnometer of capacity 500ml, detergent, water, petroleum ether and a digital weighing balance in accordance with the procedures of [14].

IV. RESULTS AND DISCUSSIONS

Results:

Table 2; Chemical properties of pumpkin seed oil

Oil property	Unit	Pumpkin variety		P-Value
		<i>c. maxima</i>	<i>c. pepo</i>	
Oil content	%	55.8 ±0.76	52.8 ±1.53	0.024*
Acid value	mgKOH/g	12.6 ±0.06	62.6 ±0.65	0.001*
Saponification value	mgKOH/g	184.0 ±5.37	187.0 ±17.54	0.768 ^{ns}
Iodine value	mgI ₂ /100g	16.0 ±0.96	15.8 ±2.22	0.886 ^{ns}
Specific gravity	dimensionless	0.933 ±0.00	0.928 ±0.00	0.158 ^{ns}
Viscosity	mm ² /sec	45.0 ±0.65	44.7 ±1.34	0.764 ^{ns}
Heating value	MJ/kg	40.5 ±0.22	40.4 ±0.68	0.789 ^{ns}
Refractive index	dimensionless	1.463 ±0.00	1.461 ±0.00	0.130 ^{ns}

* Significant (P<0.05), ^{ns} not significant (P>0.05), Mean ±Standard deviation of three determinations

Discussions:

The chemical properties of pumpkin seed oil are presented in table (2). The oil content of pumpkin seed depends on the variety of pumpkin seed; *c. maxima* variety had 5.48% more oil than *c. pepo* variety (p<0.05). In comparison to the oil content of other seeds/fruits, the oil contents in this study were higher than the oil content of soybeans (19 – 21%), mustard seed (33 – 41.5%), cottonseed (15 – 20%) [12]. It also compared higher to the oil content of some crops within the cucurbitaceae family such as “sesoswane” (24.8%), “egusi” (30.0%), “wrewre” (27.5%), “tsama” (24.8%) and the desert variety of melon (28.0%) as reported by [27], and to the twelve varieties of pumpkin cultivated in Iowa (10.9 – 30.9%) [2]. Nevertheless, the oil content in this study (52.8 – 55.8%) were lower when compared with the oil content of rubber seed (68.0%), coconut (60.0%), and castor seed (67.7%) as reported by [12], and [13] respectively. Oil content of agricultural materials gives

information on whether it is justifiable to process oil industrially from a given seed/fruit or not. According to FAO as reported in [11], any seed containing greater than 17% of oil is considered to be an oil seed, as such pumpkin seed is one, and can be utilized for the industrial vegetable oil processing.

The acid value of *c. pepo* was 396.83% higher than that of *c. maxima* ($p < 0.05$) (table 2); this indicates that oil of *c. maxima* is safer for human consumption, thus the oil of *c. pepo* requires further processing such as refining, FFA removal prior human consumption. Secondly, the result suggests that oil of *c. pepo* is more likely to undergo deterioration due to its higher acid value. The higher acid value observed in *c. pepo* may have resulted from the effect of the volume to surface area ratio on the drying time of pumpkin seed; this ratio was greater in *c. pepo*. Similar effect was observed by [1] in his work on the chemical properties of oil from cucurbitaceae cultivated in Cameroun. The acid value of oil from *c. pepo* was higher in comparison to the acid value of soybean (9.86 mgKOH/g) [28], “egusi” (4.0 mgKOH/g) [27], and rubber seed oil (8.17 mgKOH/g) [17].

Saponification value of pumpkin seed oil was not affected by variety; the saponification value of *c. pepo* is slightly higher than that of *c. maxima* by 1.63% ($p > 0.05$) (Table 2). Similarly, the saponification value in this study was lower when compared to the saponification value of *cocosnucifera* oil (246 mgKOH/g) [17], cocoa (188 – 195 mgKOH/g) [30], but lower in comparison to the saponification value of rubber seed oil (13.46 mgKOH/g) [17], annona oil (100.84 mgKOH/g) [28]. Nevertheless, it was similar with the pumpkin seed oil reported by [6] and melon seed oil (184.4 mg KOH/g) [27]. The result also suggest that pumpkin seed oil is more suitable for biodiesel processing than groundnut oil (SV= 187-196 mgKOH/g) [27], *cocosnucifera* (SV=246 mgKOH/g) [29], cocoa (SV=185-195 mgKOH/g) [30]; reference [32] found and reported that “biodiesel derived from oil with high saponification value causes exhaust emissions during burning in the engine” thus, biodiesel produced from pumpkin seed oil is most likely to be environmentally friendlier than the biodiesel processed from the seeds earlier mentioned.

Iodine value of pumpkin seed oil does not depend on the variety of pumpkin seed; the iodine value of *c. maxima* was higher than the iodine value of *c. pepo* by 1.27% ($p < 0.05$), (Table 2). The iodine values in this study compared lower to the iodine value for the refined (87.72 gI₂/100g) and the unrefined castor oil (84.8 gI₂/100g) [14], but it was higher to the iodine value of *cocosnucifera* seed oil (9.6 gI₂/100g) [29]. This result suggests that pumpkin seed oil is more suitable for biodiesel production when compared with *cocosnucifera* seed oil. Low iodine value of vegetable oil produces biodiesel with high cloud and pour points; higher cloud and pour points means poor engine performance at cold temperatures. Similarly, [31] oils with iodine value less

than 100gI₂/100g of oil are non-drying oils; correspondingly, reference [29] reported that the lower the iodine value the lesser the number of unsaturated bonds; thus the lower the susceptibility of such oil to oxidative rancidity. The result suggests that pumpkin seed oil is not suitable for ink and paint production due to its non-drying characteristics.

The refractive index of pumpkin seed oil was not affected by variety; *c. maxima* and *c. pepo* yielded similar refractive index of 1.463 and 1.461 respectively ($p>0.05$) (Table 2). These compared lower to those of beniseed (1.474), and soybean (1.465) [14], and slightly higher than the saponification value of cashew nut oil since the refractive index increases with increase in thickness of oil.

Correspondingly, the effect of variety was not significant on the specific gravity of pumpkin seed oil; *c. maxima* had a specific gravity of 0.5% higher than that of *c. pepo* ($P>0.05$) (Table 2). The specific gravity of the studied oil was higher to those of *Treculia Africana* oil (0.81) and “egusi” (0.874) as reported by [29]. However, it was lower in comparison to the specific gravity of refined castor oil (0.9589) [14], cashew kernel oil (0.962) [31]. Similarly, the specific gravity of pumpkin seed oil in both varieties were less than one (1) suggests that pumpkin seed oil is less dense than water.

The viscosity of pumpkin seed oil was not affected by variety; *c. maxima* had higher viscosity of 0.67% than *c. pepo* ($p>0.05$) (Table 2). Reference [14] reported viscosity values of 9.42 and 9.48st at 28°C for the crude and refined castor oils respectively, 41 and 56 centipore for African and Brazilian cashew kernel oils at 30°C [31], 29.10 mpa.s at 20°C for sesame oil [25].

The heating value of seed oil was not dependent on variety; the oil of *c. maxima* had a heating value of 40.5MJ/kg; this was 0.25% higher than the heating value of *c. pepo* oil ($p>0.05$) (Table 2). This result was similar to heating value of beniseed oil (41.1MJ/kg) [16], but it was lower when compared to the heating value of soybean (46.7MJ/kg), canola oil (46.3MJ/kg) [16]. Reference [33] reported the heating values of gasoline (38.2MJ/lit), fuel oil (38.7MJ/lit), natural gas (41.4MJ/m³) and coal (30.3MJ/kg) respectively. However, pumpkin seed oil has met the standards minimum heating value requirement of parent vegetable oils needed for the production of biodiesel (35MJ/kg) as contained in European standard EN 14213 and reported in [22].

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