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Tiger Nut (*Cyperus esculentus* L.) oil quality evaluation as affected by variety and processing conditions

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Abstract

Tiger nuts (*Cyperus esculentus*) are underutilized edible oil seeds cultivated across Africa with potential as a source of healthy vegetable oil. It is rich in oil with about 22.14 – 44.92% of the dry weight. This study's main aim was to evaluate the quality of tiger nut oil and determine the best variety and processing conditions for producing high-quality from it to meet the increasing demand for healthier and more sustainable vegetable oils. Applying a completely randomized design, oil was extracted mechanically using an oil expeller and the impact of variety (yellow and brown), moisture level (7%, 10% and 13%), toasting temperature (50 °C, 70 °C and 90 °C) and toasting time (10, 20 and 30 min) were investigated. Using standard procedures, five oil quality parameters were determined, namely free fatty acid (FFA), iodine value (IV), peroxide value (PV), refractive index (RI) and relative density (RD). The result shows a range of 0.22 - 0.49% for FFA, 52.62 – 80.20 (mg/100g) for IV, 2.18- 4.52 (meqO_2/Kg) for PV, 1.45 - 1.47 for RI, and 0.91 - 0.98 for RD. FFA and PV all increased as the moisture level, toasting time and toasting temperature increased, whereas the IV decreases. The RI and RD values decreased as the toasting temperature and toasting time increased but increased as the moisture level increased. ANOVA indicates that variety, moisture level, toasting temperature and toasting time have significant effects on the FFA, IV, PV, RI and RD at $P \leq 0.05$. The results show that the best oil quality was achieved at 7 % moisture content, 50 °C toasting temperature and 10 min toasting time for both varieties. The brown tiger nut has more quality oil than the yellow Tiger nut. The tiger nut oil has comparable characteristics common to vegetable oils used in food related applications and can be considered a viable alternative to common vegetable oils for food preparation. Findings from this study will help tiger nut oil processors to make the right processing pretreatment before oil extraction.

1. Introduction

Tiger-nut (*Cyperus esculentus* L.) is a species of plant of the Cyperaceae family and is a native to Egypt cultivated for its nutritional and health value [1, 2]. Tiger nut according to regional variation, historical influence and indigenous languages is called "chufa", "yellow nutsedge", "earth almond" and "ground almond" in other nations [3], while in Nigeria, it's named based on different ethnicity as "Shoho" by the Tiv ethnic group, "Aya" by the Hausa, "Ofio" by the Yoruba and "Akiausa" by the Igbo [1]. Globally, about 9000 metric tons of tiger-nut are produced annually. It has three varieties namely, black, brown, and yellow [4]. In most cultures, it is consumed as is (snack) and more recently in the production of nondairy milk.

There is growing interest in its potential health benefits and applications in different food applications. Tiger nut is a good source of antioxidants that protects the body against ageing and ailments such as cancer and heart diseases, protein, unsaturated oil, starch, fiber, essential minerals such as magnesium and potassium, vitamin C and E among others. These made it highly important in the food and medical industries as reported by [5] but in Africa especially Nigeria, tiger nut is underutilized and only processed locally into milk or consumed fresh or dried, whereas it can be processed into other forms such as oil, cake, biscuits, bread, and flour.

Fats and oil are important components of both human food and animal feed that serves as nutrient needed by the human body which are obtainable from oil seeds and nuts with different oil compositions [6, 7]. Tiger nut has 22.14 - 44.92 % of oil by dry weight as reported by Makareviciene et al. [8] and it is rich in essential fatty acids like oleic and linoleic acid, tocopherols (Vitamin E), free of Gluten, and a good moisturizer. During storage, it is reported that tiger nut starch content decreases while the reducing sugar content increases [9]. Tiger-nut oil is said to be very stable under storage without direct light and has a golden brown or golden yellow coloration depending on the variety of Tiger nut it was obtained from. The oil has nutty taste, sweet aroma and contain about 18 % saturated and 82 % unsaturated fatty acids [10], which makes a healthier oil option. Ezebor et al. [11] reported that tiger nut oil has high content of oleic acid and low polyunsaturated fatty acid, low acidity, and a lot of monounsaturated fatty acids. Aremu et al. [6] reported that the demand for edible oil is on the increase in Africa, and they rely majorly on vegetable oils such as palm oil, soya bean oil, and groundnut oil among others for meeting this need. Tiger nut oil could be another option for consumers if its oil quality properties are well defined [12]. Tiger nut being an ancient plant has not been studied exhaustively in ways that other similar plant oils have been studied. There are some research done to evaluate its physicochemical properties, and novel uses [13], but there is a need to understand and evaluate the effects of varieties and processing conditions on tiger nut oil quality and stability. Therefore, the objective of this study was to investigate tiger nut oil quality attributes mechanically extracted based on its varieties (brown and yellow) and determine how select processing conditions namely, moisture level, toasting temperature and toasting time, affect these quality attributes.

2. Materials and methods

2.1 Sample acquisition and preparations

Yellow and brown tiger nuts were purchased directly from a tiger nut farm in Katsina State, Northern part of Nigeria, and were cleaned of all dirts and foreign matters. The initial moisture content was determined following the [14] procedure of drying at 135 °C for 2 h. A total of one hundred and sixty two (162) runs of 2 kg each were applied (324 kg sample size). Eighty one (81) runs of 2 kg each of the brown and yellow varieties of tiger nut were conditioned (by rehydration) into three desired moisture levels of 7%, 10% and 13% (db) each of twenty seven (27) runs applying equation 1 as used by [14] and [15].

$$Q = W_i \left[\frac{\mathrm{M_f - M_i}}{100 - M_f}\right] \quad (1)$$

Where,

Q is the mass of moisture to be added in g,

W_1 is the initial mass of the sample in g,

M_i is the initial moisture content of the sample and

M_f is the desired (final) moisture content of the sample.

Each treatment in three (3) replications were heated (toasted) at 50 °C, 70 °C and 90 °C toasting temperature for 10 min, 20 min and 30 min toasting time respectively before the oil extraction was performed.

2.2 Determination of oil quality properties

Oil was extracted from the various prepared samples using an electrically powered motorized tiger nut oil expeller with temperature regulated barrel developed at the University of Ibadan-Nigeria. The oil was analyzed for free fatty acid (FFA), iodine value (IV), peroxide value (PV), refractive index (RI) and Relative density following standard procedures in order to investigate the effect of variety, moisture level and toasting time on the oil quality. These analyses were done at the Food Engineering Laboratory of the Department of Biosystems and Agricultural Engineering, University of Kentucky, Lexington, USA because of the interest in quality assurance, access to advanced analytical techniques and collaboration with experts. All reagents and solvents used for this study were supplied by Fisher Scientific and VWR in USA to the above stated lab.

2.2.1 *Determination of free fatty acids (FFA) content*

This was achieved using the AOAC Official Method 940.28 [17] and the procedure reported by Ogori et al. [18]. Two grams of the tiger nut oil sample was mixed with 50 mL of 95 % neutral ethyl alcohol and swirled. One to two milliliters of Phenolphthalein were added as an indicator. The solution was titrated with 0.1 N sodium hydroxide until pinkish color was observed and it terminates. The volume (V) of NaOH required to produce the first permanent pink color was recorded to evaluate the free fatty acid (FFA) content of the oil applying equation 2.

$$\text{Free fatty acid } (FFA)\,\% = \frac{28.2 \times V \times N \times 100}{w} \qquad 2$$

V = volume of NaOH used (mL),
N = Normality (concentration) of NaOH (0.1 N),
w = weight of oil used (g)

2.2.2 *Determination of iodine value*

Iodine value of the extracted tiger nut oil was determined following the method described by AOAC Official Method 941.21 [19] and ISO 3961:2018 [20]. About 2 g of the oil was delivered to a 300 mL conical flask with ground-in stopper and was mixed with 25.0 mL carbon tetrachloride and sealed. 25.0 mL Hanus solution was added and sealed, it was shaken for one minute and left in a dark room for 30 minutes with occasional shaking. 10.0 mL of 15% potassium iodide and 100 mL water (boiled and cooled) were added, sealed, and shaken for 30 seconds. 1 mL of soluble starch was added and the mixture titrated with 0.1 mol/l sodium thiosulfate to obtain iodine value when the blue color changed to milky white or colorless. Likewise, a blank test was performed to obtain blank level. The iodine value was calculated using Equation 3.

$$\text{Iodine value (IV)} = \frac{126.9\,(a-b) \times N \times 100}{W} \qquad 3$$

Where a =Volume (mL) of 0.1 mol/l sodium thiosulfate consumed in the blank test, b = Volume (mL) of 0.1 mol/l sodium thiosulfate consumed in the test, N = Normality of sodium thiosulfate,
W = Weight of sample (g),

2.2.3 *Determination of peroxide*

The Peroxide values (PV) of tiger nut oil was determined according to ISO 3960:2017 [21, 18]. The oil sample (5 g) was weighed into a 200 mL conical flask and mixed with 30 mL of glacial acetic acid and 20 mL of chloroform and mixed thoroughly by swirling the flask. Potassium iodide (0.5 mL) was added, and the mixture was left in the dark for 1 minute with occasional swirling, followed with further addition of 30 mL of distilled water. The mixture was titrated with 0.1 N sodium thiosulfate solution with 0.5 mL of 1.0% soluble starch as indicator until the dark blue color disappears. A blank sample titration was carried out in the same manner but with no oil added. The Peroxide values (PV) were calculated using Equation 4 below.

$$\text{Peroxide value} = \frac{(a-b) \times N \times 1000}{\text{Weight (g) of the sample}} \qquad 4$$

Where, a =Volume (mL) of 0.1 mol/l sodium thiosulfate consumed in the blank test, b = Volume (mL) of 0.1 mol/l sodium thiosulfate consumed in the test, N = Normality of sodium thiosulfate and W = Weight of sample.

2.2.4 *Determination refractive index*

N-1E Handheld Refractometer (Atago, Japan) was used in this determination as described by ISO 6320:2017 [22]. Before introducing the sample, water at 30 °C was circulated around the glass slide to keep its temperature uniform and through the eyepiece of the refractometer, the dark portion viewed was adjusted to be in line with the intersection of the cross. One drop of the tiger nut oil sample was transferred into the glass slide (prism) of the refractometer after proper cleaning with ethanol and cotton. The sample is allowed to spread all over the prism surface, the scale was read where the boundary line intercepts the scale by looking through the eyepiece and recorded as the refractive index of the sample and the mean values calculated.

2.2.5 *Determination of relative density*

The procedures for specific density determined followed by [23] was applied. Density bottle was used to determine the density of the tiger nut oil. A clean and dry bottle of 25 mL capacity was weighed (W_0) and then filled with the oil, stopper inserted and reweighed to give (W_1). The oil was substituted with water after washing and drying the bottle and

Table 1. Tiger nut oil free fatty acid (FFA) investigated as influenced by variety, moisture level, toasting temperature and toasting time.

Moisture Level (%)	Toasting Temperature (°C)	Toasting Time (min)	Brown Tiger nut FFA (%)	Standard Deviation	Yellow Tiger nut FFA	Standard Deviation
7	50	10	0.24^{aaa}	0.004	0.22^{aaa}	0.003
		20	0.27^{aab}	0.001	0.25^{aab}	0.001
		30	0.32^{aac}	0.002	0.28^{aac}	0.002
	70	10	0.25^{aba}	0.004	0.26^{aba}	0.001
		20	0.28^{abb}	0.001	0.28^{abb}	0.001
		30	0.34^{abc}	0.002	0.31^{abc}	0.002
	90	10	0.26^{aca}	0.001	0.35^{aca}	0.003
		20	0.28^{acb}	0.001	0.39^{acb}	0.003
		30	0.32^{acc}	0.002	0.41^{acc}	0.001
10	50	10	0.29^{baa}	0.004	0.27^{baa}	0.017
		20	0.32^{bab}	0.000	0.31^{bab}	0.004
		30	0.36^{bac}	0.001	0.33^{bac}	0.003
	70	10	0.30^{bba}	0.004	0.30^{bba}	0.001
		20	0.33^{bbb}	0.003	0.33^{bbb}	0.002
		30	0.37^{bbc}	0.001	0.35^{bbc}	0.001
	90	10	0.30^{bca}	0.001	0.40^{bca}	0.001
		20	0.33^{bcb}	0.001	0.44^{bcb}	0.008
		30	0.36^{bcc}	0.001	0.46^{bcc}	0.002
13	50	10	0.30^{caa}	0.022	0.35^{caa}	0.003
		20	0.34^{cab}	0.001	0.36^{cab}	0.000
		30	0.36^{cac}	0.003	0.35^{cac}	0.002
	70	10	0.33^{cba}	0.001	0.37^{cba}	0.002
		20	0.35^{cbb}	0.001	0.39^{cbb}	0.003
		30	0.38^{cbc}	0.002	0.36^{cbc}	0.002
	90	10	0.37^{cca}	0.002	0.47^{cca}	0.002
		20	0.39^{ccb}	0.003	0.49^{ccb}	0.009
		30	0.37^{ccc}	0.002	0.49^{ccc}	0.020

Note: The first, second and third letters represents the effects of moisture content, toasting temperature and toasting time on oil quality respectively. Means with the same superscript are not significantly different along the same column.

weighed to give (W_2). The specific gravity (Sp.gr) was calculated applying equation 5.

$$\text{Sp.gr} = \frac{\text{Mass of the sample}}{\text{Mass of an equal volume of water}} = \frac{W_1 - W_0}{W_2 - W_0} \quad 5$$

Where W_0 = Weight of container, g, W_1 = Weight of container and oil, g, W_2 = Weight of container and water, g.

2.3 Oil quality data analysis

The oil quality properties were determined in four replications and statistically analyzed at 95% confidence level using SPSS version 20 software (IBM, USA) and a Duncan test was performed to separate the means to identify the major areas of significance.

3. Results and discussion

3.1 Effects of variety, moisture level and toasting time on Free Fatty Acid

The free fatty acid (FFA) from this study ranged from 0.22-0.49% as presented in Table 1, with the tiger nuts at 7% moisture level toasted for 10 min at toasting temperature of 50°C having the least values, while tiger nut at 13% toasted for 30 min at 90°C toasting temperature had the highest FFA values. The results show that the FFA increases as the moisture level, toasting time and toasting temperature increases. Analysis of variance (ANOVA) revealed that variety, moisture level, toasting time and toasting temperature all have significant effects on the FFA value at $p<0.05$. The range of FFA values obtained in this study are all <0.6 % which is the recommended range of FFA for fats and oil by the World Health Organization and Food and Agricultural Organization of the United Nations. [18] reported a range of 0.39 - 0.41(%) and 0.19 - 0.22 (%) for stored brown and yellow tiger nut oil and this report is slightly low from the result observed in this study.

This difference could be because of the different oil extraction methods used and the effect of the heating

Table 2. Iodine value (IV) of tiger nut oil investigated as influenced by variety, moisture level, toasting temperature and toasting time.

Moisture Level (%)	Toasting Temp (°C)	Toasting Time (min)	BT nut IV (mg/100g)	Standard Deviation	YT nut IV (mg/100g)	Standard Deviation
7	50	10	76.83^{aca}	0.045	76.46^{aca}	0.044
		20	76.33^{acb}	0.024	76.27^{acb}	0.040
		30	76.17^{acc}	0.035	76.19^{acc}	0.009
	70	10	66.83^{aba}	0.045	56.62^{aba}	0.325
		20	70.33^{abb}	0.024	60.35^{abb}	0.559
		30	75.21^{abc}	0.045	70.27^{abc}	0.090
	90	10	57.63^{aaa}	0.315	52.62^{aaa}	0.325
		20	61.36^{aab}	0.556	55.69^{aab}	0.165
		30	71.27^{aac}	0.094	60.27^{aac}	0.090
10	50	10	78.47^{bca}	0.014	78.74^{bca}	0.040
		20	78.14^{bcb}	0.031	77.84^{bcb}	0.003
		30	77.45^{bcc}	0.017	77.24^{bcc}	0.026
	70	10	74.47^{bba}	0.010	62.27^{bba}	0.029
		20	77.13^{bbb}	0.016	67.89^{bbb}	0.609
		30	78.23^{bbc}	0.062	74.85^{bbc}	0.467
	90	10	63.28^{baa}	0.037	58.27^{baa}	0.029
		20	68.77^{bab}	0.636	64.55^{bab}	0.357
		30	75.84^{bac}	0.480	68.85^{bac}	0.666
13	50	10	79.84^{cca}	0.061	79.85^{cca}	0.004
		20	79.54^{ccb}	0.031	79.21^{ccb}	0.014
		30	79.13^{ccc}	0.036	78.88^{ccc}	0.029
	70	10	78.17^{cba}	0.539	68.45^{cba}	0.022
		20	79.16^{cbb}	0.040	72.32^{cbb}	0.050
		30	80.20^{cbc}	0.622	77.32^{cbc}	0.592
	90	10	69.46^{caa}	0.014	65.45^{caa}	0.022
		20	73.32^{cab}	0.050	70.15^{cab}	0.279
		30	78.32^{cac}	0.586	75.66^{cac}	0.020

Note: The first, second and third letters in the superscript represents the effects of moisture content, toasting temperature and toasting time on oil quality respectively. Means with the same superscript are not significantly different along the same column. BT – Brown Tiger; YT – Yellow Tiger; Temp – Temperature;

temperature and time applied in this study. The reports are similar in line with the report by [24] for tiger nut, [25] report for sesame seed oil, report on roasted soybean by [26]. The low FFA values obtained in this study are an indication that tiger nut oil would be stable over long period of time without rancidity and peroxidation as reported by [6] for several oil seeds in Nigeria.

3.2 Effects of variety, moisture level and toasting time on Iodine value

The experimental result of Iodine value is reported in Table 2, and it ranged from 52.62-80.20(mg/100 g) with the Brown tiger nut at 13% moisture level toasted for 30 min at 70°C toasting temperature having the highest value of iodine while the least value was obtained from the yellow tiger nut at 7% moisture level toasted for 10 min at 90°C toasting temperature.

The moisture level, toasting time, toasting temperature, and variety were reported to have significant effect on the iodine value at $p<0.05$ after Analysis of variance. The range of iodine value obtained in this research is within the acceptable iodine value for olive oil published by [27] fats and oil regulations and [28] for existing named vegetable oils. The iodine value of tiger nut oil from this study is below 100 mg/100g and it indicates that the tiger nut oil is a nondrying oil (it does not harden but remains in liquid form when exposed to air) [6]. [29] reported 67.35 mg/100g as iodine value of tiger nut oil extracted mechanically and this value is within the value range reported in this study. [30, 31] reported similar observations in their study of rapeseed oil and canola oil respectively. The differences in the results may be as a result of the treatment the tiger nut was exposed to before extraction of its oil. This result is in line with the iodine value of Castor seed oil reported by [32].

Table 3. Average results of the tiger nut oil Peroxide value (PV) investigated as influenced by variety, moisture level, toasting temperature, and toasting time.

Moisture Level (%)	Toasting Temperature (°C)	Toasting Time (min)	Brown Tiger nut PV (meq O_2/Kg)	Standard. Deviation	Yellow Tiger nut PV (meq O_2/Kg)	Standard. Deviation
7	50	10	2.33^{aaa}	0.0321	2.61^{aaa}	0.0321
		20	2.74^{aab}	0.0100	2.79^{aab}	0.0115
		30	2.92^{aac}	0.0058	3.32^{aac}	0.0586
	70	10	2.38^{aba}	0.0153	3.35^{aba}	0.0954
		20	2.54^{abb}	0.0208	3.78^{abb}	0.0600
		30	2.90^{abc}	0.0208	3.96^{abc}	0.0153
	90	10	3.35^{aca}	0.0100	3.18^{aca}	0.1400
		20	3.77^{acb}	0.0265	3.81^{acb}	0.0231
		30	3.89^{acc}	0.0400	3.75^{acc}	0.0100
10	50	10	2.23^{baa}	0.0208	2.42^{baa}	0.0000
		20	2.66^{bab}	0.0115	2.82^{bab}	0.0700
		30	2.93^{bac}	0.0643	3.06^{bac}	0.0153
	70	10	2.33^{bba}	0.0100	3.95^{bba}	0.0100
		20	2.35^{bbb}	0.0100	3.97^{bbb}	0.0200
		30	2.66^{bbc}	0.0173	4.27^{bbc}	0.0737
	90	10	3.85^{bca}	0.0058	3.56^{bca}	0.0305
		20	3.95^{bcb}	0.0153	4.07^{bcb}	0.0473
		30	4.35^{bcc}	0.0100	3.95^{bcc}	0.0058
13	50	10	2.18^{caa}	0.0252	2.25^{caa}	0.0416
		20	2.50^{cab}	0.0115	2.62^{cab}	0.0252
		30	2.71^{cac}	0.0200	2.95^{cac}	0.0058
	70	10	2.26^{cba}	0.0115	4.01^{cba}	0.0436
		20	2.26^{cbb}	0.0608	4.31^{cbb}	0.0458
		30	2.62^{cbc}	0.0100	4.48^{cbc}	0.0404
	90	10	3.98^{cca}	0.0305	3.74^{cca}	0.0058
		20	4.35^{ccb}	0.0173	4.29^{ccb}	0.0436
		30	4.52^{ccc}	0.0300	4.45^{ccc}	0.0058

Note: The first, second and third letters in the superscript represents the effects of moisture content, toasting temperature and toasting time on oil quality respectively. Means with the same superscript are not significantly different along the same column.

3.3 Effects of variety, moisture level and toasting time on Peroxide value

Peroxide value is an important quality parameter that deduces oxidation of the oil [33]. The peroxide value of the experimental samples analyzed ranged from 2.18-4.52 (meqO_2/Kg) as shown in Table 3, with the tiger nuts having their least peroxide values at 13% moisture level toasted for 10 min at toasting temperature of 50°C and the highest peroxide values obtained from both tiger nut at moisture content of 13% toasted for 30 min at 90°C toasting temperature. The peroxide value was observed to increase as toasting time and toasting temperature increased but decreased as the moisture level increased at 50°C and 70°C toasting temperatures, although an increase was observed as the moisture level increases at 90°C toasting temperature. Analysis of variance indicated a significant effect of the moisture level, toasting time, toasting temperature, and variety on the peroxide value at 95% confidence level. The peroxide value range obtained in this research is within the acceptable limit of <10 meqO_2/Kg peroxide value for edible oil as reported for olive oil, cotton seed oil, soya beans oil, maize oil, palm oil among several others published by [27] fats and oil regulations and the [28]. [26] reported the same trend in their study of roasted soybean.

The result obtained in this study is different from the range of 0.71-1.36 meqO_2/Kg reported by [10] and 15.76 meqO_2/Kg reported by [29] for tiger nut oil peroxide value and this difference could be because of the different oil extraction, drying methods applied and the differences in moisture content applied in this study. Because of the high toasting temperatures used, the thermal oxidation of the oils is triggered, leading to a higher range of peroxide value than the one reported by [10]. The results corresponded with the peroxide value reported by [24] for Almond seed oil and Soybean seed oil reported by [33].

Table 4. Average results of the tiger nut oil Refractive index (RI) investigated as influenced by variety, moisture level, toasting temperature and toasting time.

Moisture Level (%)	Toasting Temperature (°C)	Toasting Time (min)	Brown Tiger nut RI	Standard. Deviation	Yellow Tiger nut RI	Standard. Deviation
7a	50c	10b	1.47[acb]	0.001	1.46[acb]	0.001
		20a	1.45[aca]	0.024	1.46[aca]	0.001
		30a	1.46[aca]	0.000	1.46[aca]	0.001
	70b	10	1.47[abb]	0.001	1.45[abb]	0.001
		20	1.46[aba]	0.000	1.45[aba]	0.001
		30	1.47[aba]	0.001	1.45[aba]	0.001
	90a	10	1.45[aab]	0.001	1.45[aab]	0.001
		20	1.45[aaa]	0.001	1.45[aaa]	0.001
		30	1.45[aaa]	0.001	1.45[aaa]	0.012
10b	50	10	1.47[bcb]	0.001	1.47[bcb]	0.001
		20	1.47[bca]	0.000	1.47[bca]	0.001
		30	1.47[bca]	0.001	1.47[bca]	0.001
	70	10	1.47[bbb]	0.000	1.46[bbb]	0.001
		20	1.47[bba]	0.000	1.46[bba]	0.001
		30	1.47[bba]	0.001	1.46[bba]	0.003
	90	10	1.46[bab]	0.000	1.46[bab]	0.001
		20	1.46[baa]	0.001	1.45[baa]	0.001
		30	1.46[baa]	0.001	1.45[baa]	0.002
13c	50	10	1.47[ccb]	0.001	1.47[ccb]	0.001
		20	1.47[cca]	0.000	1.47[cca]	0.001
		30	1.47[cca]	0.001	1.47[cca]	0.000
	70	10	1.47[cbb]	0.001	1.46[cbb]	0.003
		20	1.47[cba]	0.000	1.46[cba]	0.001
		30	1.47[cba]	0.001	1.46[cba]	0.002
	90	10	1.46[cab]	0.003	1.46[cab]	0.002
		20	1.46[caa]	0.004	1.46[caa]	0.000
		30	1.46[caa]	0.002	1.46[caa]	0.002

Note: The first, second and third letters in the superscript represents the effects of moisture content, toasting temperature and toasting time on oil quality, respectively. Means with the same superscript in the same column are not significantly different

3.4 Effects of variety, moisture level and toasting time on Refractive Index

The experimental samples displayed a refractive index range of 1.45-1.47 as reported in Table 4, and the brown tiger nut sample at moisture level 7% toasted for 20 min at 50°C toasting temperature is observed to have the least value while the yellow tiger nut sample at moisture level 13% toasted for 10 min at 50°C toasting temperature alongside brown tiger nut sample at moisture level 13% toasted for 30 min at 70°C toasting temperature all have the highest refractive index values. The refractive index value was observed to decrease as the toasting temperature and toasting time increased but increases as the moisture level increased from 7% to 13% respectively. Analysis of variance reported a significant effect of moisture level, variety, toasting time and toasting temperature on the refractive index value at $p<0.05$. Most of the range of refractive index values obtained in this research is within the acceptable range of refractive index 1.4677-1.4707 as published by [27, 28] fats and oil regulations while some are little below the acceptable value which could be because of the influence of the pre-treatment given to the tiger nut before oil extraction or because of its unrefined characteristics. [29] reported 1.48 refractive index for tiger nut oil extracted mechanically but without any treatment. The refractive index value of the tiger nut oil is within the report on Refractive index of Soybean seed oil, castor seed oil, Pumpkin seed oil, and almond seed oil by [24, 33-37] reported a trend similar to the observation in this study.

3.5 Effects of variety, moisture level and toasting time on Relative Density

The relative density of the various samples experimented is represented in Table 5 and it ranged from 0.91-0.98. The least value of the relative density was obtained from the yellow tiger nut sample at 7%

Table 5. Average results of the tiger nut oil Relative Density (RD) investigated as influenced by variety, moisture level, toasting temperature, and toasting time.

Moisture Level (%)	Toasting Temperature (°C)	Toasting Time (min)	Brown Tiger nut RD	Standard Deviation	Yellow Tiger nut RD	Standard Deviation
7	50	10	0.94^{ccb}	0.001	0.93^{ccb}	0.001
		20	0.96^{cca}	0.002	0.98^{cca}	0.002
		30	0.94^{cca}	0.002	0.97^{cca}	0.002
	70	10	0.94^{cbb}	0.000	0.93^{cbb}	0.001
		20	0.95^{cba}	0.001	0.95^{cba}	0.002
		30	0.96^{cba}	0.002	0.95^{cba}	0.001
	90	10	0.93^{cab}	0.001	0.93^{cab}	0.001
		20	0.94^{caa}	0.002	0.93^{caa}	0.002
		30	0.94^{caa}	0.001	0.95^{caa}	0.001
10	50	10	0.93^{bcb}	0.000	0.92^{bcb}	0.001
		20	0.95^{bca}	0.001	0.97^{bca}	0.001
		30	0.92^{bca}	0.000	0.96^{bca}	0.002
	70	10	0.94^{bbb}	0.001	0.92^{bbb}	0.001
		20	0.95^{bba}	0.001	0.94^{bba}	0.001
		30	0.94^{bba}	0.002	0.94^{bba}	0.001
	90	10	0.92^{bab}	0.001	0.92^{bab}	0.001
		20	0.93^{baa}	0.001	0.93^{baa}	0.002
		30	0.93^{baa}	0.001	0.95^{baa}	0.001
13	50	10	0.92^{acb}	0.001	0.91^{acb}	0.000
		20	0.94^{aca}	0.001	0.94^{aca}	0.004
		30	0.91^{aca}	0.001	0.93^{aca}	0.001
	70	10	0.93^{abb}	0.001	0.92^{abb}	0.001
		20	0.94^{aba}	0.002	0.94^{aba}	0.002
		30	0.92^{aba}	0.002	0.93^{aba}	0.001
	90	10	0.92^{aab}	0.000	0.92^{aab}	0.002
		20	0.93^{aaa}	0.002	0.92^{aaa}	0.001
		30	0.92^{aaa}	0.001	0.92^{aaa}	0.001

Note: The first, second and third letters in the superscript represents the effects of moisture content, toasting temperature and toasting time on oil quality, respectively. Means with the same superscript in the same column are not significantly different.

moisture level toasted at 20 min while the yellow tiger nut at 13% moisture level toasted at 10 min had the highest value. The relative density of the samples showed an increase simultaneously as the moisture level increased but decreased as the toasting time and temperature increased. Analysis of variance revealed a significant effect of the moisture level, toasting time and variety on the specific gravity or relative density value at 5% probability error. Majority of the relative density of the experimented samples falls within the acceptable value of specific gravity value for olive oil, soya beans oil and cotton seed oil as published by [27, 28] fats and oil regulations, while little is above the maximum acceptable value which was because of the maximum acceptable value which was because of the influence of the pre-treatment given to the tiger nut before oil extraction. The result reported is in line with the relative density reported for Castor seed oil, Pumpkin seed oil, Almond seed oil by [35], and [24] respectively. In the reported studies [38-40] on Roasted coconut oil, roasted peanut oil and sesame oil all reported a similar trend of observation. The relative density of the tiger nut oil was less dense than that of water which means, the oil is light and unsaturated which does not have an extreme lubricating potential. This is an indication tiger nut oil will be a good ingredient in the production of creams since the oil can easily be distributed or applied on human skin.

4. Conclusions

This study evaluated the quality of tiger nut oil as affected by the processing conditions and variety. Free fatty acid(FFA), iodine value (IV), peroxide value (PV), refractive index (RI) and relative density (RD) of two varieties of tiger nut oil extracted mechanically were evaluated to ascertain the effects of variety (brown and yellow) and processing conditions namely; moisture content (7 %, 10 % and 13 %), toasting temperature (50 ˚C, 70 ˚C and 90 ˚C) and toasting time (10, 20 and 30 min) on the extracted oil. The brown tiger nut was observed to have a better quality in terms of the indices measured than the yellow tiger nut oil. And the treatment with the best oil quality was the brown tiger nut at 7 % moisture content, 50 ˚C toasting temperature and 10 min toasting time. The FFA, IV, PV, RI and RD for both varieties of tiger nut oil under the ultilised processing conditions were recorded to be in the range of 0.22 - 0.49 (%), 52.62 - 80.20 (mg/100g), 2.18 - 4.52 (meqO_2/Kg), 1.45 - 1.47 and 0.91 - 0.98 respectively. It was observed that tiger nut oil quality for the two varieties reduced as the moisture level, toasting temperature and time increased. The results data shows that both variety and processing conditions have significant impact on the evaluated quality of tiger nut oil at $P \leq 0.05$. The tiger nut oil quality from both varieties investigated are within the range acceptable for vegetable oils and can be considered a viable alternative to common vegetable oil in food related applications.

Authors' contributions

Idea conception, experimental design, experimentation, manuscript, writing of the original draft, P.A.O.; Idea conception, project supervision, review and editing, A.K.A.; Idea conception, writing-review and editing, M.O.O.; Experimentation, review and statistical analysis, T.O.O.; Project supervision, experimentation, writing–review and editing, A.A.A.

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Conflicts of interest

The authors declare there are no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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