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INFLUENCE OF MOISTURE CONTENT ON THE YIELD AND QUALITY OF TROPICAL ALMOND (*Terminalia catappa*) SEED OIL

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ABSTRACT

The effect of moisture content on the yield and quality of oil obtained from almond seeds was investigated in this study. The oil was extracted using solvent extraction method at 4.17%, 8%, 12% and 16% almond seed moisture contents. The extracted oils were characterized using standard methods. Mean oil yield values of 51.90%, 48.62%, 48.87% and 37.02% were obtained for the samples respectively. The specific gravity, density and smoke point ranged from 1.09-1.15, 0.99-1.05 and 154-173 respectively. The acid value (mg/KOH/g), free fatty acid (mg/KOH/g) and saponification values (mg/KOH/g) were 8.80, 7.60, 2.80, 2.00, 4.40, 3.80, 1.40, 1.00, and 176.70, 193.55, 204.77, 196.35 at the four moisture content levels of 4.17%, 8%, 12% and 16% respectively. The peroxide value (mEq/kg) and iodine value (g/100g) ranged from 0.20-1.00 and 95.70-107.65 respectively. The oil yield decreased with increase in moisture content of the almond seeds, with the highest oil yield obtained at 4.17% and the lowest yield obtained at 16% moisture contents which is in line with other oil bearing seeds. The oil is suitable for edible purposes since its nutritional values are within the range specified for edible oils. The oil is also suitable for industrial applications due to its high saponification values and can therefore be recommended for soap making.

1. INTRODUCTION

Tropical almond (*Terminalia catappa*) is an underutilized crop which belongs to a group of nuts with hard shelled seeds enclosing a single edible kernel (Adu *et al*., 2013). The plant also called Indian almond, is a large spreading tree now distributed throughout the tropics in coastal environments. The seeds are often of small sizes and difficult to extract from the nuts; these factors may have contributed to its lack of use in many areas (Adu *et al*., 2013). The tree is tolerant to strong winds, salt spray, and moderately high salinity in the root zone if grown principally in freely drained and well aerated sandy soils. The almond tree produces drupe fruits, just like the true almond and many other plants. The seed inside the fruit is edible when fully ripe (Dasrao *et al*., 2015). The tree is highly prevalent in tropical regions of Asia, Africa, and Australia (Thomson and Evans, 2006). The fruit bark and leaves have been commonly used as folk medicine for anti-diarrheal, antipyretic and haemostatic purposes (Adu *et al*., 2013). The leaves have been used for the prevention and treatment of hepatitis and liver-related diseases. Oil extracted from the dried nuts is edible and used for cooking in parts of South America (Adu *et al*., 2013). There is an increasing need to search for oils from non-conventional sources to augment the available ones and also to meet specific applications (Kyari, 2008). Due to a high demand for vegetable oils in view of the population growth, rising standards of living, as well as consumer preference, arising partly from health considerations (Oresanya, 2000), there is need to evaluate many other seeds for oil production.

2. MATERIALS AND METHODS

2.1. Material Collection and Preparation of Samples

Mature almond seeds used in this study were obtained from trees within the Federal University of Technology Minna, Bosso campus, Niger state, Nigeria. The succulent portion of the fruit was scrapped off from the hard core nut using a knife to obtain the pulp. The hard core nut was then cracked to obtain the seeds.

2.2. Moisture Content Determination

The moisture content was determined according to the method described by the Association of Analytical Chemists (AOAC, 2004). The initial moisture content (MC) of the sample was determined on wet basis using oven dry method at 105^{o}C for 24 hours in % wet basis as:

$$M.C = \frac{W1-W2}{W1} \times 100 \tag{1}$$

The initial moisture content of the seeds was calculated to be 4.17%. The sample was then divided into four parts; sample A (4.17%. moisture content) was left as the control, while samples B, C, and D were reconditioned to moisture contents of 8, 12 and 16% respectively. The samples of the desired moisture content were prepared by adding the specified amount of distilled water, sealing in separate polythene films and refrigerating at 5^{o}C for one week. The quantity of water added was calculated from the following formula as reported by Sacilik *et al.* (2003).

$$Q = \frac{W_i(M_f - M_i)}{(100 - M_f)} \tag{2}$$

Where: W_i= Initial mass of sample, W_f =Final moisture content of sample, M_i = Initial moisture content of sample, Q = Mass of water to be added

2.3. Extraction of Oil using Solvent Extraction Method

The soxhlet apparatus was used to extract oil from the seeds. The extraction process was replicated three times and the oil was recovered by solvent evaporation. The oil yield for each sample was obtained using Equation 3 as reported by Nkafamiya *et al.* (2007).

$$\% \text{ Oil yield} = \frac{Weight\ of\ sample\ before\ extraction - Weight\ of\ sample\ after\ extraction}{Weight\ of\ sample\ before\ extraction} \times 100 \quad (3)$$

2.4. Determination of Oil Quality

The physicochemical properties of the oil were used to determine the quality of oil produced. They properties investigated include specific gravity, density, cloud point, smoke point, flash point, acid value, free fatty acid value, saponification value, peroxide value, and iodine value. They were determined according to procedures described by AOAC (2006) standard methods.

3. RESULTS AND DISCUSSION

3.1. Effect of Moisture Content on Oil Yield

The effect of moisture content on the oil yield of almond seed is presented in Table 1. Samples A, B, and C have values that are comparable to those reported by Adu *et al*., (2013) who reported a range of 38-54% for almond seed. However, sample D at 16% moisture content had a yield below 38% which shows that there is a reduction of the oil yield at moisture contents above 12%. From Table 1 it can be seen that at all levels, oil yield from the seeds were significantly different. Sample A, recorded the highest oil yield of 51.90 ± 0.01% at 4.17% moisture content, while sample D had the lowest yield 37.01 ± 0.01% at 16% moisture content. The result shows that the higher the moisture content, the lower the oil yield of almond seed which is similar to reports for other oil bearing seeds. Orhevba *et al*. (2013) reported a maximum oil recovery of 24.86% for neem seed kernel oil at 8.1% moisture content, and stated that the yield reduced to 15.62% at 16.6% moisture content. They added that higher moisture content led to lower oil yield of neem; Akinoso (2006) reported that moisture content has highest influence on sesame oil yield; he added that to increase oil yield, moisture content has to be reduced. Adejumo *et al.,* (2013) also reported that *moringa oleifera* seeds yielded oil of 38.48% at 10% moisture content, but reduced to 27.53% when the moisture content was increased to 20%.

Table 1: Percentage Oil Yield of almond seed

Sample	Moisture content (%)	Oil yield (%)
A	4.17	51.09 ± 0.01^{d}
B	8	48.62 ± 0.02^{b}
C	12	48.87 ± 0.01^{c}
D	16	37.01 ± 0.02^{a}

Values are means of triplicate determination ± standard deviation of mean
Note: superscripts with different alphabets shows significant difference (P<0.05)

3.2. Effect of Moisture Content on the Oil Quality

The effect of moisture content on the quality parameters of almond seed oil is presented in Tables 2 and 3. The quality parameters were compared to those of FAO/WHO (2009) and International standard for edible oils (NIS, 1992) as reported by Angaye and Maduelosi (2015) and Adegbe *et al.* (2016).

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Table 2: Physical properties of almond seed oil

Properties	Sample A(4.17%)	Sample B(8%)	Sample C(12%)	Sample D(16%)	*standard for edible oil
Specific gravity	1.15±0.02[b]	1.09±0.01[a]	1.14±0.02[b]	1.15±0.01[b]	0.9-1.16
Density (g/cm^3)	1.00±0.01[b]	1.05±0.05[c]	1.00±0.02[b]	0.99±0.01[a]	-
Cloud point (°C)	7.00±0.01[c]	6.00±0.01[b]	6.00±0.02[b]	5.00±0.01[a]	8-10
Smoke point (°C)	154.00±0.32[a]	173.00±0.49[d]	160.00±0.20[b]	161.00±0.58	200-250
Flash point (°C)	167.00±0.11[a]	178.00±0.24[b]	187.00±0.09[c]	189.00±0.02	300-350

*FAO/WHO (2009) and NIS (1992) standards for edible vegetable oil

Table 3: Chemical Properties of almond seed oil

Properties	Sample A (4.17%)	Sample B(8%)	Sample C (12%)	Sample D (16%)	*standard for edible oil
Acid value (mg/KOH/g)	8.80±0.75[d]	7.60±0.82[c]	2.80±0.02[b]	2.00±0.08[a]	<4
Free fatty acid (mg/KOH/g)	4.40±0.75[d]	3.80±0.82[c]	1.40±0.02[b]	1.00±0.08[a]	5.78-7.28
Saponification value (mg/KOH/g)	176.70±0.15[a]	193.55±0.06[b]	204.77±0.01[d]	196.35±0.02[c]	181.4±2.60
Peroxide value (mEq/kg)	1.00±0.01[c]	1.00±0.02[c]	0.20±0.45[a]	0.60±0.58[b]	10
Iodine value (g/100g)	96.80±0.11[b]	95.70±0.05[a]	104.00±0.01[c]	107.65±0.20[d]	80-106

*F.A.O/W.H.O. (2009) International standard for edible oils

3.2.1. Specific gravity

The specific gravity determined for samples A, B, C, and D (1.15 ± 0.02, 1.09 ± 0.01, 1.14 ±0.02, and 1.15 ± 0.01) were within the range specified by FAO/WHO international standard for edible oil reported by Adegbe *et al.,* (2016) which is 0.9-1.16. The specific gravity decreased from sample A to sample B, and then increased up to sample D in a non-linear manner, as shown in Table 2. Adejumo *et al.*; (2013) also reported a non-uniform linear increase in specific gravity of *moringa oleifera* as the moisture content increased. It can be seen in Table 2 that there is no significant difference in the specific gravity at 4.17, 12, and 16% moisture contents. All values obtained are greater than 1.00, which implies that almond seed oil is denser than water.

3.2.2. Density

The density values increased from sample A up to sample B and then decreased up to sample D in a non-linear manner as can be seen in Table 2. Sample B had the highest density value of 1.05 ± 0.01 g/cm^3 at 8% moisture content, while sample D had the lowest value of 0.99 ± 0.01 g/cm^3 at 16% moisture content. The values as shown in Table 2 indicate that there is no significant difference in the density at 4.17 and 12% moisture contents. However, there is a significant difference in the density at 8 and 16% moisture. Hence, it can be concluded that the density of almond seed oil decreased with increase in moisture content above 8%. Aviara *et al.*; (2014) reported an increase in density from 325 to 465 kg/m as moisture increased from 7.1 to 32.0% (d.b.) for seed and from 321 to 705 kg/m for kernel as the moisture content increased from 5.3 to 22.0% (d.b.)

3.2.3. Cloud point

The cloud point values recorded for samples B and C at 8 and 12% moisture showed no significant difference. All the values obtained for the different levels were lower than the recommended standard of NIS (1992) for edible vegetable oils as reported by Angaye and Maduelosi (2015) which is 8-10°C; however, the values fell within the value (6-12 °C) reported for palm olein (Akinoso *et al.*, 2006). The cloud point decreased from sample A to B, and remained unchanged up to C and then dropped to sample D. Hence it can be inferred that the higher the moisture content, the lower the cloud point of the oil samples.

3.2.4 Smoke point

The smoke point is the temperature at which the smoke is first detected (Barku *et al.*, 2012). The smoke point values at all moisture levels showed significant difference as seen in Table 2. The smoke point value increased from sample A to B, decreased from B to C, and then increased up to D. All samples had values lower than those reported by NIS (1992) which is 200-250°C. Sample B at 8% moisture had the highest smoke point of 173 ± 0.01°C. According to Adejumo et al (2013), smoke point which is the temperature, at which the smoke is first detected, tends to be higher for oil extracted at lower seed moisture contents;

3.2.5. Flash point

The flash point values obtained showed significant difference as seen in Table 2. All values recorded were lower than the NIS (1992) standard as reported by Angaye and Maduelosi (2015) for edible vegetable oil which is 300-350°C. They also pointed out that high flash point is indicative of the suitability of the oil for frying. Increase in moisture content brought about a corresponding increase in flash point from samples A to D, as can be seen in Table 2.

3.2.6. Acid value

Acid value is used as an indicator for edibility of oil and suitability for use in the paint industry (Barku *et al.*, 2012). Samples A and B had acid values that were above FAO/WHO standard as reported by Adegbe *et al.,* (2016) which is a maximum of 4 mgKOH/g. However, samples C and D had values that agreed with the standard.. The acid value at all moisture levels showed significant difference as can be seen in Table 3. Barku *et al.* (2012) reported a mean acid value of 0.787 for almond seed oil. Since the acid value of the oil obtained from almond seed of 12% moisture content and above was lower than the maximum permissible acid level of 4mgKOH/g, it implies that the almond seed oil is suitable for direct consumption.

3.2.7. Free fatty acid (FFA)

The free fatty acid value measures the extent to which the glycerides in the oil have been decomposed by lipase action. Hence, as rancidity is usually accompanied by free fatty acid formation, the free fatty acid is often used as general indication of the condition and edibility of the oil (Adejumo *et al.*, 2013). All the samples had values lower than the FAO/WHO standard which is 5.78-7.28 mg/KOH/g. Samples at all levels of moisture showed significant difference in the free fatty acid value as shown in Table 3. Barku *et al.* (2012) reported FFA of 0.387mg/KOH/g for almond seed oil.

3.2.8. Saponification value

Sample A had a value (176.70 Mg/KOH/g) lower than the recommended international standard for edible oil reported by Adegbe *et al.* (2016) while samples B, C, and D had values (193.55, 204.77 and

196.35 Mg/KOH/g) higher than the standard which is 181.4 Mg/KOH/g . The saponification value increased with increase in moisture content. Barku *et al.,* (2012) reported mean saponification value of 168.27 for almond seed oil which is lower than that observed for this study at all levels of moisture content. Saponification value is used in checking adulteration. The high levels of saponification recorded indicate the low level of impurity in the oil (Barku *et al.,* 2012). The almond oil could therefore be useful industrially for soap, shampoo and paints making.

3.2.9. Peroxide value

All the peroxide values (1.00, 1.00, 0.20 and 0.60 (mEq/kg) recorded were significantly lower than the standard specified by FAO/WHO (2009) standard for edible oil as reported by Adegbe *et al.* (2016) which is 10 mEq/kg. The peroxide value which is a measure of the oxygen content is used to monitor the development of rancidity through the evaluation of the quantity of peroxide generated in the product. The peroxide value remained the same up to 8% moisture content, dropped significantly up to 12% moisture content and then climbed up again to 16% moisture content. The low peroxide values are indicative of low levels of oxidative rancidity of the oil samples and also suggest strong presence or high levels of antioxidants (Barku *et al*., 2012). The peroxide values are low and this point to the fact that the oils may not be easily susceptible to deterioration and this agrees to the report of Barku *et al.* (2012).

3.2.10. Iodine value

Samples A, B, and C had values (Table 3) within the range specified by FAO/WHO for edible oil which is between 80-106 g/100g. Sample D however had a value above the standard specified value. The iodine value decreased from sample A to B, but increased from B to D as can be seen in Table 3. The iodine value of the oil is a measure of the unsaturated acid present. It also indicates the non-drying qualities. Therefore, the test measures the amount of iodine consumed by the acid. The greater the iodine value, the greater the unsaturation and thus the greater the liquidity. This indicates that sample D has the highest unsaturation. The iodine values at all levels of moisture differed significantly, but were within the standard range specified. Hence *Terminalia catappa* oil can be considered edible based on the iodine value observed.

4. CONCLUSION

It can be concluded that almond seed oil yield decreases with increase in seed moisture content with the highest yield of 51.90% recorded at 4.17% seed moisture content. All the quality parameters investigated were affected by different levels of moisture content. The seed oil at all levels of moisture investigated gave a good indication of long shelf life due to the low peroxide values. The low acid values of the oil recorded above seed moisture of 8% indicate its suitability for edible purposes. The oil is also suitable for industrial applications due to its high saponification values and can therefore be recommended for soap making.

5. ACKNOWLEDGMENT

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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