Influence of extraction temperature and moisture content on the yield and physicochemical properties of hog plum (*Spondias mombin*) kernel oil

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Abstract: This study investigated the extraction and characterisation of hog plum seed kernel. Oil was extracted using solvent method; normal hexane was used as solvent for the extraction process. The study was carried out at moisture contents of 8.03%, 10.57% and 12.00%, and at extraction temperatures of 40°, 50°C and 60°C. The physicochemical properties of the oil investigated were density, saponification value, acid value and free fatty acid. The statistical analysis done showed that moisture content and extraction temperature significantly affected the oil yield; the maximum oil yield in this study was found to be 13.42% at moisture content of 12.00% and extraction temperature of 60°C. The physicochemical properties of the investigated oils were within the requirements of edible oil quality: saponification value was 192.2 mg KOH g^{-1}, acid value was 2.80 mg KOH g^{-1}, free fatty acid was 1.40%w/ w, and density was 0.825 g cm^{-3}. These results revealed that the seed has potential use as an industrial raw material and food source.

Keyword: extraction temperature; moisture content; physicochemical properties; oil yield.

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1 Introduction

Hog plum, a perennial and fructiferous tree, is a member of the family *Anacardiaceae*. The *Anacardiaceae* family, represented by about 80 genera and 600 species, produces tasty fruits, good wood and compounds which are useful industrially and medically (Davies, 2016). According to Adedokun et al. (2010), it is native to Peru, Brazil, Bolivia, Venezuela, Columbia, the three Guianas, Southern Mexico, Costa Rica, Belize and the West Indies. The tree can be found in tropical and sub-tropical areas of America, Asia and Africa (Adedokun et al., 2010).

Esua et al. (2016) reported that the seed kernel contains carbohydrate (40.56%), ash (8.09%), crude fibre (31.86%), moisture content (8.48%), crude protein (7.73%), crude fat (3.28%), calcium (1317 mg kg^{-1}) and copper (7.68 mg kg^{-1}). Phytochemical analyses showed the presence of tannins (0.06%) and phytate (0.0022%). The seed kernel of hog plum can be a potential source of nutritious food, with nutrient composition higher than that of its fruit pulp (Esua et al., 2016). The seed kernel of hog plum can be a potential source of nutritious food with good anti-anaemic and anti-diabetic function for its high iron and zinc contents (Esua et al., 2016).

Edible oils are important in several industries such as foods, energy, cosmetics, pharmaceuticals or lubricants (Neagu et al., 2013). Edible oils are important constituents of our daily diet, which provide energy, vital fatty acids to the body and serve as a carrier of fat-soluble

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vitamins. The physical properties of vegetable oils primarily depend on the composition i.e. its biological origin and temperature (Coupland and McClements, 1997).

Physicochemical properties are important parameters that determine the overall quality and stability of a system (Neagu et al., 2013). It is also important to determine the purity and identification of oil. According to Amira et al. (2014), characteristic properties are properties that depend on the nature of the oil. Example of these properties are iodine value and saponification value, these properties are used to characterize oil irrespective of the location or source, while peroxide value, free fatty acid value, acid value and density change with location (Shorunke, 1986).

Considerable attention is required for analysis of the characteristics of the oil extracted from hog plum kernel. This study was therefore conducted to determine some of the physical and chemical properties of hog plum kernel using solvent extraction to extract oil at different extraction parameters (temperature and moisture content).

2 Materials and methods

2.1 Materials

2.1.1 Fruits collection

Hog plum fruits were obtained from hog plum trees around the Federal University of Technology, Akure, Ondo state, Nigeria. The fruits were washed to remove the dirt and the seeds were removed from the pulps

2.1.2 Seed preparation

The study was carried out at the Federal University of Technology, Minna (9.5836°N, 6.5463°E), Niger State, Nigeria. The fruits were washed and the seeds removed. The seeds were also washed to remove particles of the pulp from them and sun dried for 4 days at an average temperature and relative humidity of 29.25°C and 76% respectively. The seeds were dried enough to facilitate easy removal of the fibre from the seed kernel.

2.1.3 Kernel removal

Preparing the seeds for oil extraction involved removing the outer layers (the fibres), to expose the kernel. It was necessary to crack the seeds open in order to obtain kernels for further preparation and processing. The fibre coating was removed with a knife; a handful of seeds were placed on the table surface and scraped individually, before removing the kernels and the waste fibre coating. The seed kernels were then milled into powder with a milling machine to obtain a fine consistency to maximise particle surface area, to particle sizes of about 0.6 mm.

2.2 Method

2.2.1 Moisture content determination

The moisture content was determined based on the method described by Aviara et al. (2014) for Shea nut. After the determination of the initial moisture content, the milled samples were bagged and sealed. The moisture content (wet basis) obtained after drying was 8.30%.

2.2.2 Moisture content variation

The samples were reconditioned to obtain the remaining desired moisture contents of 10% and 12% by adding calculated amounts of water to the samples. After the addition of water, they were sealed and refrigerated at a temperature 5°C for 7 days. The amount of water added to vary the moisture content was calculated using equation 1 reported by Bart-Plange et al. (2012).

$$Q = \frac{W_i(M_f - M_i)}{100 - M_f} \quad (1)$$

Where: Q is the amount of water to be added (g), W_i is the initial weight of sample (g),M_i is the initial moisture content of seeds (%),and M_f is the final moisture content (%).

The moisture content of the samples used for the study was 8.03%, 10.57% and 12.00%. Oil was thereafter extracted from the prepared samples using the Soxhlet extractor (solvent extraction method).

2.2.3 Oil Extraction

Oil extraction was done using the solvent extraction method as described by Okoro (2013) with slight modification. The same mass of the ground kernels (flour) were completely wrapped in a filter paper, 300 mL of normal Hexane (n-hexane) was poured into a round bottom flask. 20 g of the sample was placed in the thimble and placed at the centre of the extractor; it was inserted in the round bottom flask containing n-hexane and then placed on the heating mantle. The condenser openings were covered with aluminium foil for safety reasons.

The Soxhlet was heated to the desired temperature. When the solvent was boiling, the vapour rose through the vertical tube into the condenser at the top. The liquid condensate dripped into the filter paper in the centre of the thimble, which contains the solid sample to be extracted. The extract then seeped through the pores of the thimble and filled the siphon tube where it flowed back down into the round bottom flask and the samples were left to run for 8hours. It was then removed from the tube, dried in the oven, cooled and weighed again to determine the amount of oil extracted.

The resulting mixture (*miscella*) containing the hexane/oil mixtures were collected and a similar procedure were followed for recovery of solvent from the oil. When it was determined that the hexane had been fully evaporated, the oil was transferred into a sample bottle for analysis. The experiment was repeated at the different temperatures for the samples based on their different moisture contents. The weight of oil extracted was determined for each extraction.

2.2.4 Oil yield

The samples were extracted in triplicates. The percentage oil content of the seed was calculated using the weight loss of the sample.

$$Y = \frac{W_i - W_f}{W_i} \times 100\, Y \qquad (2)$$

Where, Y is the oil yield (%),W_i is the weight of sample before extraction (g), and W_f is the weight of sample after extraction (g).

2.2.5 Characterization of Hog plum kernel oil

Physical and chemical properties of hog plum seed kernel oil produced were determined in accordance with Bilal et al. (2013), Adamu (2014), Mohammed-Dabo et al. (2012) and The American Oil Chemist Society [AOCS] (2010) methods of analysis. The properties determined were relative density, saponification value, acid value and free fatty acid.

2.3 Data analysis

Analysis of variance was used to check if there was interactive effect between moisture content and extraction temperature on the yield of oil. Significant effects at 95% confidence interval were analyzed to obtain the table of interaction between moisture content and extraction temperatures using one-way Analysis of variance (ANOVA). Duncan multiple range test (DMRT) was used for the mean separation. The software used for the data analysis was SPSS 22.0, 2006 version.

3 Results and discussion

The result of the study (oil yield and the physicochemical properties of hog plum kernel oil) are presented in Tables 1 and 2.

Table 1 Effect of kernel moisture contents and extraction temperatures on plum seed kernel oil yield

Samples	Moisture content %	Temperature ^{0}C	Oil yield %
1	8.05	40	10.80
2	8.05	50	10.92
3	8.05	60	11.15
4	10.57	40	11.20
5	10.57	50	11.37
6	10.57	60	12.04
7	12.00	40	13.03
8	12.00	50	13.30
9	12.00	60	13.42

Table 2 Hog plum seed kernel oil characteristics

Property	Unit	Value
Density	(g cm^{-3})	0.825
Saponification value	(mg KOH g^{-1})	192.2
Acid value	(mg KOH g^{-1})	2.81
Free fatty acid (FFA)	%w/w	1.40

Results obtained (Table 1) showed that the oil yield was different at different moisture contents and extraction temperatures. Analysis of the result showed that there was significant difference ($p \leq 0.05$) in the oil yield of the kernel at different level of moisture content and temperature. The highest oil yield in this study (13.42%) was obtained when the moisture content was 12.00% at 60^{o}C; this was then used for the characterization. This highest oil yield is low when compared with those reported for Soursop seed (33.87%), palm oil (30.2%), hemp seed oil (32.4%) and soya bean oil (21.4%) by Okoro (2013), Nursyazana and Nazri (2014) and Nathan (2013) respectively, but compares well with that of cotton seed (15%) and more than that of corn (3.0% to 6.5%)

reported by Alexander (2009).

Statistical analysis done to determine the effect of moisture content and temperature on the yield (Table 3) showed that the temperature and moisture content had significant effect on the yield.

Table 3 Effect of moisture content and temperature on oil yield

Variable	Oil yield (%)
Moisture (M)	
8.03	10.96^{c}±0.53
10.57	11.53^{b}±0.05
12.00	13.25^{a}±0.23
Sig.	**
Temperature (T)	
40	11.68^{c}±0.27
50	11.86^{b}±0.35
60	12.20^{a}±0.24
Sig.	**
Interaction	
M *T	**

Note: Means on the sample column with different superscript for each variable are significantly different at ($p \leq 0.05$) along the rows. Values are Mean ± Standard deviation. ** Significant at 5% level.

Statistical analysis also shows the interaction between the moisture content and temperature and that they had significant effect on the yield as shown in Table 4.

Table 4 Interaction between moisture content and temperature for oil yield

Moisture content (%)	Temperature (°C)		
	40	50	60
8.03	10.8^{d}	10.92^{c}	11.15^{c}
10.57	11.2^{c}	11.37^{c}	12.04^{b}
12.00	13.03^{a}	13.30^{a}	13.42^{a}

Note: Means with different superscripts are significantly different.

The oil yield at moisture content of 12.00% at 40°C, 50°C and 60°C were not significantly different from each other but were significantly higher than other treatments. The oil yield of hog plum kernel at 12.00% moisture content was the highest (13.42%) this is lower than the moisture content reported by Kumar et al. (2018), who obtained oil yield of 30.0% at 17.23% moisture content for Jatropha Seed. Udoh et al. (2017) also reported the highest yield of 34.13% from Soursop seed at 13.51% moisture content. The highest oil yield was observed at 60ºC, this is in line with Suwari et al., (2018), who reported an increase in oil yield from 50ºC - 65ºC from seed kernel of Feunkase.

The decreasing order of yield was 12.00%/60°C > 12.00%/50°C> 12.00%/40°C > 10.57%/60°C> 10.57%/50°C > 10.57%/40°C > 8.03%/60°C > 8.03%/50°C > 8.03%/40°C. This implies that as the moisture content of the hog plum kernel and the extraction temperature increased the higher the yield of hog plum seed kernel.

The physicochemical properties as shown in Table 2, were used to determine the stability of the oil to oxidation, the application, the edibility and the compositional quality of the oil.

The relative density of hog plum kernel oil obtained in this study was 0.825 g cm^{-3}. Although the value is low when compared with the relative densities of rosigold mango kernel seed oil (0.874 g cm^{-3}), palm oil (0.931 g m^{-3}), hemp seed oil (0.893 g m^{-3}) and soya bean oil (0.908 g m^{-3}) reported by Nursyazana and Nazri (2014) and Nathan (2013). The hog plum kernel oil relative density value (0.825 g cm^{-3}) implies that the oil is less dense than water due to absence of heavy element or hydroxyl groups in it. According to Kakani and Amit (2004), value of relative density of any oil gives an idea about its heaviness (dense nature) when compared with that of distilled water.

The free fatty acid value was 1.40%w/w. The two parameters that determine the application of oil suitable for either edible or industrial process are free fatty acid and acid value. The free fatty acid obtained in this study agrees with that of palm kernel oil (1.35%) (Amira et al., 2014). The free fatty acid value is below the value of 5% reported by NIFOR (1989). Onyeike and Acheru (2002), reported that oil used as food must have free fatty acid value below 3%. The food value of a greasy substance depends on the quantity of free fatty acids, for example, butyric acid out of butter and lauric acid for lauric oils (Matos et al., 2009).

Acid value can be used to check the level of oxidative deterioration of oil by enzymatic or chemical oxidation (Onuekwusi et al., 2014). It is a measure of the degree of unsaturation of oil and it corresponds to the amount of potassium hydroxide (KOH) required to neutralize free fatty acids (Asuquo et al., 2010). The acid value is used as an indicator for the edibility of the oil (Akpan et al., 2006). The lower the acid value of oil, the fewer free fatty acids it contains which makes it less exposed to rancidity (Asuquo et al., 2010). According to Esuoso and Odetokun (1995), acid value of the oil suitable for edible purposes should not exceed KOH 4 mg g^{-1}. The acid value obtained in this study (2.81 mg KOH g^{-1}) is higher than those reported for bean seed oil (2.77 mg KOH g^{-1} and 2.74 mg KOH g^{-1} (Ekpa and Ekpe, 1995), palm kernel oil (2.7 mg KOH g^{-1}) but lower than coconut oil and groundnut oil (5.55 mg KOH g^{-1}, 9.0 mg KOH g^{-1}) as reported by Amira et al. (2014).The acid value of the hog plum seed kernel oil studied fell within the allowable limits for edible oils and less exposed to rancidity. Therefore, the oil is suitable for use as food and is a good source of raw material for industries.

Saponification value determines the quantity of potassium hydroxide (in mg) needed to neutralize the acids and saponify the esters contained in 1 g of the lipid (Asuquo et al., 2010). The saponification value of the hog plum kernel (192.2 mg KOH g^{-1}) agrees with that of groundnut oil (191.5 mg KOH g^{-1}), but it is lower than that of palm kernel and coconut oil (280 mg KOH g^{-1} and 257.5 mg KOH g^{-1}), *Adenopus breviflorus* (Akintayo and Baeyer, 2000), rubber seed oil (Asuquo et al., 2012) and peanut oil in the range of 187 – 250 mg KOH g^{-1}. According to Onuekwusi et al. (2014), the higher the saponification value of oil, the higher the lauric acid content of that oil. The high saponification value of 192.2 mg KOH g^{-1} obtained in this study makes the seed suitable for industrial purposes. According to Onuekwusi et al. (2014), the lauric acid content and the saponification value of oil serve as important parameters in determining the suitability of oil in soap making. The saponification value of the oil could also be used as a parameter for checking adulteration of oil sample (Amoo et al., 2004). The saponification value obtained in this study therefore projects the oil as good in areas of soap making. It was also within the recommended range (188-198 mg KOH g^{-1}) for edible oils (FAO/WHO, 1993).

4 Conclusions

This study has shown that hog plum kernel has potentials for use as food and industrial raw materials; it has established that hog plum seed kernel oil, like most contemporary edible oils, also contain high amount of unsaturated fatty acids required by human body as essential fatty acids hence the desirability of hog plum seed kernel oil in human diet.

The percentage oil content of hog plum seed kernel was found to be 13.42% at 12.00% moisture content; the oil yield increased (by average 2%) with increasing extraction temperature (by average 20°C). From the statistical analysis done, the moisture contents and extraction temperatures significantly affected the oil yield. Despite the low oil yield, the oil has an advantage in that it is of good quality and could be recommended suitable for industrial usage. Another positive factor regarding this raw material is the fact that the kernel (the source of the oil), is a waste material, thus, it is readily available and affordable.

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