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# Physico-chemical properties of crude oil of *Khaya senegalensis* (Desr.) A. Juss according to bioclimatic zones in Chad

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## Abstract

The mature seeds of *Khaya senegalensis* are from 2 to 2.5 cm long and weigh 289 g per 1000 seeds. These seeds contain about 67% oil by weight. This oil, which is fairly rich in oleic acid (66%), is used in West Africa for cooking, for cosmetics, as an insecticide and in traditional medicine. Prospecting to enhance the development of this oil in Chad, the present study aims to determine the physico-chemical properties of this oil according to bioclimatic zones. The density, acidity, peroxide value, moisture content and percentage of impurities were the parameters studied. The results showed that the crude oil of the seeds of *K. senegalensis* has the qualities close to those of other edible oils. The study also showed that climate has influenced the physico-chemical parameters of this oil. Further and more research investigations are necessary to guide decisions on the valorisation and large-scale production of this oil.

**Keywords:** *Khaya senegalensis,* seed crude oil, physico-chemical parameters, valorisation, bioclimatic zone, Chad

## INTRODUCTION

The seeds of *Khaya senegalensis* look like flat discs and measure 2 to 2.5 cm long and weigh 289 g per 1000 seeds. These seeds contain about 67% oil by weight (Jøker and Gaméné, 2003; Karigar *et al*., 2010; Aliyu *et al*., 2012; Ayo *et al*., 2013; Idu *et al*., 2014b). Quite rich in oleic acid (66%), the oil is used in West Africa as food oil and for cosmetics (Jøker and Gaméné, 2003; Orwa *et al*., 2009; Idu *et al*., 2014b). It has also been mentioned as an insecticide in Nigeria (Bamaiyi *et al*., 2006; Salih and Yahia, 2015).

In Chad, its uses have been in combination with other medicinal substances in order to treat stomach aches and syphilis. Used alone, the oil heals rheumatism, infants' constipation and intestinal worms. Ayo *et al*. (2013) have reported that *K. senegalensis* seed oil is non-drying and consists of long chain fatty acids and bioactive compounds of therapeutic and prophylactic importance. In 2016, The Chadian authorities have begun to promote neglected sectors such as groundnuts, sesame, arabic gum (Non-Timber Forest Product) and shea (wild fruit tree). The surrounding populations of the species areas in Chad produce oil from these seeds and this oil is widely used locally and generates income to the communities. However, this Non-Timber Forest Product (NTFP) has not received any particular attention until now to be valorised. Therefore, with a view to highlight the importance of this oil, the present study aims to characterize its physico-chemical according to bioclimatic zones.

## MATERIAL AND METHODS

### Oil sample collection and sampling

Quarter litre of crude oil of the species seed was purchased from each of 10 women oil extractors in each bioclimatic zone. In order to avoid mixing the selected oil with others, the oil extractions were attended. Furthermore, two samples of the collected oil were randomly selected from each zone for physico-chemical parameters determination.

### Physical parameters

Physico-chemical parameters of the species seed crude oil included density, acidity, peroxide value, saponification value, impurity content, moisture content and volatile matter. They were obtained in accordance with the standard procedure of the CCOQDA (Centre de Contrôle de Qualité des Denrées Alimentaires) of Chad for the chemical parameters and the French standards AFNT 60 214 and 60 212 for the physical parameters.

Oil density is the ratio of the weight of a volume of this oil at temperature T, to the weight of the same volume of water at the same temperature T (37°C for these samples). The density is always less than 1 and is not only for unsaturation function but also for oxidation or polymerisation. It is expressed in grams per ml or kilograms per litre and given by the following formula (Wolff, 1968):

$$d = \frac{P3 - P1}{P2 - P1} \text{ , with:}$$

P1: weight of empty pycnometer expressed in grams;

P2: weight of filled pycnometer with distilled water expressed in grams;

P3: weight of filled pycnometer with oil expressed in grams

## Chemical parameters

### Acidity

Fat acidity is the percentage of free fatty acids conventionally expressed as oleic acid (Houmba *et al.*, 2016). There generally indicate the edibility of oils and is obtained by the relation:

$$a = (V \times 28{,}2 \times N)/P \quad \text{(Wolff, 1968) with,}$$

V: volume of used soda;

N: normality of the solution;

P: mass of the test sample.

### Index of peroxide (Ip)

Peroxide index (Ip) is the number of milliequivalents of active oxygen per kilogram of fat. It is given by the formula:

$$Ip = (V \times T \times 1000)/M, \quad \text{with:}$$

V: number of milliliters of standardised sodium thiosulphate solution used for the test and corrected according to the results of the blank test.

T: exact normality factor of the used thiosulphate solution;

M: mass of the test sample expressed in grams.

### Index of saponification (Is)

The saponification value is the amount of potash expressed in milligrams required to saponify 1 gram of oil. The saponification value is obtained by the formula:

$$Is = ((C1 - C2) \times 28)/M, \quad \text{with:}$$

M: mass of the test sample expressed in grams;

C1: number of milliliters of hydrochloric acid used in the blank test;

C2: number of milliliters of hydrochloric acid used in the test with the oil

### Impurity content

The impurities are flocculated with phosphoric acid and separated from the oil by filtration. The filtration also retains impurities that are not soluble in acetone. The rate of impurities is obtained by the relation:

$$\% \text{ impurity} = ((P1 - P0)/PE) \times 100, \quad \text{with:}$$

P0: weight of the filter alone;

P1: weight of the filter with impurities;

PE: weight of the oil.

### Humidity

The moisture and volatile matter contents are given by the formula:

$$H\% = ((P2 - P3) / (P2 - P1)) \times 100, \quad \text{with:}$$

P1: weight of the empty crystallizer;

P2: weight of the crystallizer with oil before heating;

P3: weight of the crystallizer with oil after heating.

## RESULTS

The analyses showed that the seed oil of *K. senegalensis* taken from the Sudanian zone was on average denser (0.92 g.ml⁻¹) than the oil taken from the Guinean zone (0.89 g.ml⁻¹). The oil densities of Sudanian (0.92 g.ml⁻¹) and Sudano-Sahelian (0.90 g.ml⁻¹) zones were close. As regards to acidity, it was noted that it was higher for Sudano-Sahelian (1.87) zone than it was for the other zones (Table 1). The seed oil of Sudanian zone was indeed more basic. Although the difference was not too great for peroxide value, it should be noted that the seed oil of Sudano-Sahelian zone (2.92) contained more oxygen than that of Guinean (2.89) and Sudanian (2.86) zones. In addition, the seed oil of Guinean zone had a higher saponification index (162) than that of Sudano-Sahelian (159) and Sudanian (158) zones. This means that the oils of Guinean zone would require more potash for its saponification than the oils of other two zones.

For the moisture content of the oils, it was noted that the oil of Sudanian zone contained a very low moisture content. Sudano-Sahelian zone contained more impurities (0.28%) in oils than Sudanian zone (0.18%) and Guinean (0.16%) zone.

**Table 1: Physico-chemical properties of *K. senegalensis* seed oils of three climatic zones in Chad**

| Parameters | Zones | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| | Guinean | | Sudanian | | Sudano-Sahelian | |
| | ZGH1 | ZGH2 | ZSH1 | ZSH2 | ZSSH1 | ZSSH2 |
| **Density** | 0.88 | 0.89 | 0.92 | 0.91 | 0.90 | 0.89 |
| **Acidity** | 1.44 | 1.33 | 1.26 | 1.37 | 1.97 | 1.77 |
| **Peroxide** | 2.95 | 2.75 | 2.87 | 2.85 | 2.91 | 2.93 |
| **Saponification** | 163 | 161 | 159 | 157 | 161 | 156 |
| **Humidity** | 0.07 | 0.05 | 0.06 | 0.08 | 0.04 | 0.04 |
| **Impurity** | 0.15 | 0.17 | 0.16 | 0.20 | 0.29 | 0.26 |

## DISCUSSION

Six parameters (density, acidity, peroxide, saponification, moisture and impurity) were determined to characterize the sample oil. This is because of the possibilities offered by the laboratory where the analyses were carried out.

The density of most oils, whether mineral or vegetable, is between 0.840 and 0.960 (Aïssi *et al., 2009a)*. The density values obtained on *K. senegalensis* oil in Chad vary from one climatic zone to another. Thus, the oil samples of Guinean (0.880-0.890), Sudanian zone (0.910-0.920) and Sudano-Sahelian (0.890-0.900) zones are within the density range of most vegetable or mineral oils. On the other hand, oils of Sudanian zone are slightly denser than those from the other two zones. Thus, the oil from this zone is more unsaturated or more polymerised than those of Guinean and Sudano-Sahelian zones. These findings are comparable to those obtained in the literature included in table 2. There were also close to the values of olive oil where the standard shown by *codex alimentarius* is between 0.910 and 0.916 (*Codex Alimentarius*, 1999). This may be one of the reasons why the oil of Olive is used in cooking and cosmetics (Jøker and Gaméné, 2003; Idu *et al*. 2014a).

Acidity as the percentage of oleic acid is used to assess the degree of alteration of an oil (Aïssi et al., 2009b). Oleic acid is responsible of oil rancidity (Cissé, 2010), (Meftah *et al*., 2014). A low acidity value of an oil at ambient temperature may characterise the purity and stability of this oil (Tchiégang-Meguéni, 2003). The acidity values of the crude oil of *K. senegalensis* of the different climatic zones of Chad are between 1.33-1.44 mg/g, 1.26-1.37 mg/g and 1.77-1.97 mg/g respectively for Guinean zone, Sudanian zone and Sudano-Sahelian zone. These values are lower than most of the usual oils such as soybean oil (max.3mg/g), sunflower oil (max.4mg/g) and olive oil (2-6 mg/g) especially for virgin olive oil as a reference value. Thus, the oils of the seeds of *K. senegalensis* are pure, stable and the potentially edible oils. It should also be recognized that oils of Sudanian zone with value of 1.77 to 1.97 are more potential for trading.

The peroxide values of an oil evaluate the primary level of this oil oxidation (Meftah *et al*., 2014). Oil peroxide value assesses also the oxidative deterioration It is a very useful criterion with a satisfactory sensitivity to assess the first stages of oxidative deterioration of this oil (Louni, 2009). It is therefore linked to storage conditions and extraction methods. It also indicates the rancidity of an oil and a low peroxide value indicates that it is likely to be less rancid at ambient temperature. The peroxide values of 2.75-2.95 meq/kg, 2.85-2.87 meq/kg and 2.91-2.93 meq/kg for oils respectively of Guinean zone, Sudanian zone and Sudano-Sahelian zone, *K. senegalensis* seed oil can be considered less rancid oil at ambient temperature.

The saponification index states the fatty acid content (free and esterified) in the oil (Cissé, 2010; Meftah *et al*., 2014). Therefore, its high value can mean that the oil is potential for soap making.

The values of 161.00-163.00 mg/g for Guinean zone oils, 157-159 mg/g for Sudanian zone oils and 156-161 mg/g for Sudano-Sahelian zone were relatively high. These values may indicate that *K. senegalensis* seed oil contained fatty acids with high molecular weight that can be comparable to oils of palm, olive, soybean, cotton or flax (Ayo *et al*., 2013; Idu et al., 2014b). Therefore, this oil can be used well to make soap.

Oil moisture is essential for the degree of seed maturity as oil percentage increase when moisture content decrease like in the case of the fruit of olives (Cherrat and Mendel, 1997; Kroun *et al*, 2004). The standards call for a moisture content of 0.2 or less (Cherrat and Mendel, 1997). The results obtained on *K. senegalensis* oil of different climatic zones of Chad (Guinean zone: 0.05-0.07; Sudanian zone: 0.06-0.08; Sudano-Sahelian: around 0.04) showed the low moisture levels, although varying according to bioclimatic zones. This could be interpreted in several ways. So, either the water added to the paste to extract the oil was completely removed during separation, or the seeds used are fully ripe and free of any attacks that could increase moisture. In this context, Kroun *et al*. (2004) found for olive oil that incomplete removal of

**Table 2: Relative densities of some vegetable oils**

| Oils type | Relative density | References |
|---|---|---|
| **Sunflower oil** | 0.918 - 0.923 | Siham and Nesrine, 2021, *Codex Alimentarius*, 1999 |
| **Soybean oil** | 0.919 - 0.925 | Kirilov *et al*, 2015, *Codex Alimentarius*, 1999 |
| **Peanut oil** | 0.912 - 0.920 | Karoui *et al*., 2021, *Codex Alimentarius*, 1999 |
| **Olive oil** | 0.913 - 0.916 | Kirilov *et al*., 2015, Ben Belal and Tebbakh, 2020, Boutata, 2018, *Codex Alimentarius*, 1999 |
| **Palm oil** | 0.891 - 0.899 | Kouassi e*t al*., 2017., Karoui e*t al*., 2021, *Codex Alimentarius*, 1999 |
| **Coconut oil** | 0.908 - 0.921 | Karoui *et al*., 2021, Euphrasie, 2016, *Codex Alimentariu*s, 1999 |
| **Corn oil** | 0.917 - 0.925 | Karoui *et al*., 2021, Sitorus, 2015 |
| **Rapeseed oil** | 0.910 - 0.920 | Kirilov *et al*., 2015, *Codex Alimentarius*, 1999 |
| **Flaxseed oil** | 0.926 - 0.930 | Vaitilingom, 2013, *Codex Alimentarius*, 1999 |
| **Cottonseed oil** | 0.918 - 0.926 | Karoui *et al*., 2021, *Codex Alimentarius,* 1999 |
| **Safflower oil** | 0.922 - 0.927 | Kirilov *et al*., 2015, *Codex Alimentarius*, 1999 |

water during separation, an incomplete ripening of the seeds or a seed attack by diseases (insects, fungi, etc.) are among the factors that raise the moisture content. Therefore, with these very low moisture contents (0.04-0.08 overall), the oil of *K. senegalensis* seed can be easy to store for long-term use.

A crude oil, regardless of how it is obtained, even if it has been perfectly cleaned of all insoluble matter, contains a number of impurities which consist of dust and other foreign matter insoluble in organic solvents and which can be extracted and evaluated (Cherrat and Mendel, 1997). The findings of this study showed that the impurity values (Guinean zone: 0.15-0.17; Sudanian zone: 0.16-0.20; Sudano-Sahelian: 0.26-0.29) are slightly higher than the standard of 1% of impurities by the *codex alimentarius* for virgin olive oil. This difference can be seen in the way the oil of *K. senegalensis* is extracted in local areas. The standard impurity rate of 1% of Olive oil is from manufactured extraction. Thus, impurity matters should be less in comparison to traditional extraction (Ohimain *et al.*, 2013). However, between climatic zones, the difference is insignificant. Therefore, much effort should be locally made in order to improve the quality of the oil of *K. senegalensis* in Africa and especially in Chad.

## CONCLUSION

This study focusing on some physico-chemical parameters of crude oil of *K. senegalensis* seed showed that this crude oil presented the properties close to those of most known food oils. The study also revealed that climate has influenced the physico-chemical parameters of this oil. Further and more research investigations are necessary to guide decisions on the valorisation and large-scale production of this oil.

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