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REVIEW ARTICLE

STUDY OF THE NUTRITIONAL VALUE OF *IRVINGIAEXCELSA* KERNELS FROM POKOLA IN THE REPUBLIC OF CONGO

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ABSTRACT

This study investigated the nutritional value of *Irvingiaexcelsa* (Payo) kernels from Pokola, Republic of Congo. We conducted physicochemical analyses according to the AOAC standard. Analyses of these kernels revealed that they have a low water content (2.89±1.15%), which explains their long shelf life. Fiber, ash, and protein contents were also low (1.22±0.44%; 3.90±0.14%; and 7.28±1.45%, respectively). However, the lipid content was high (43.97±2.47%), as was the carbohydrate content (44.85%), and the calculated energy value was 604 kcal/100g. Some chemical indices of the extracted oil were determined. The acid value is 2.95±0.26 mg KOH/g; the peroxide value is 1.92±0.12 meq O_2/kg; and the saponification value is 151±1.26 mg KOH/g. *Irvingiaexcelsa* kernels have appreciable nutritional quality; their oil is unaltered and is of interest in the cosmetics industry.

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INTRODUCTION

In the Republic of Congo, as in most sub-Saharan African countries, food security is one of the major challenges facing governments. It is a state in which a population enjoys physical and economic access to sufficient, safe, and nutritious food to meet their energy needs and food preferences for a healthy and active life (World Food Summit, 1996). Unfortunately, in recent years, the food and nutritional situation in Congo has steadily deteriorated. Faced with this alarming situation, it is necessary to adopt measures aimed at strengthening agricultural structures with a view to achieving food self-sufficiency. Congolese vegetation contains an incalculable number of non-timber forest products (NTFPs) (Louzolo 2017). These are wild or domesticated plants whose ecological and socioeconomic value is little or unknown, but which provide economic and nutritional support for local populations (Ingram *et al*., 2010). They can therefore be of invaluable assistance in the fight for food security. Prominent among these NTFPs is the species *Irvingiaexcelsa* (locally called "Payo"). This tree is found wild in the humid forest areas of tropical Africa (Harris, 1996). These kernels, usually harvested by farmers and indigenous people, are particularly valued for their high fat content (Gallois *et al.,* 2020). *Irvingiaexcelsa* is a naturally wild tree (Lowe *et al.,* 2000; Atangana *et al.,* 2002). It is found in dense forests where annual rainfall varies between 1500 and 3000 mm (Ayuk *et al.,* 1999; Ainge & Brown, 2001), in cocoa plantations, in scrubland around villages and along logging roads (Ladipo, 2000; Gallois *et al.,* 2020). In the Republic of Congo, it grows mainly in the departments of Sangha, Cuvette Ouest and Likouala, but is better known to the people of Sangha (Ouesso and its surroundings). It is also found, along with other similar species, in other Central African countries, including the Democratic Republic of Congo, Gabon, Cameroon and the Central African Republic (Harris, 1996; Ainge & Brown, 2001; Gallois *et al.,* 2020). However, data on the physicochemical composition of its kernels are not available, unlike the species *Irvingiagabonensis*, *Irvingiawomboulou* and *Irvingiasmithii* which are well known (T Silou *et al.,* 2004; 2011;

Loumouamou *et al.,* 2013). This is how we set ourselves the objective of studying the nutritional value of *Irvingiaexcelsa* kernels from Pokola, in the Sangha department. More specifically, it involves determining the water, lipid, protein, mineral, carbohydrate and crude fiber contents, and deducing the energy value and determining some chemical indices of the oil extracted from these kernels.

MATERIALS AND METHODS

Plant Material: The plant material in this study consists of pits extracted from the fruits of *Irvingiaexcelsa* (Payo), harvested between June and August 2023 in Pokola, Sangha Department. Before shipment to Brazzaville, they were sun-dried to prevent the growth of mold, which can affect their quality after one day. Figures 3 and 4 show the trunk and pits of *Irvingiaexcelsa*, respectively.

Figure 1. Trunk of Irvingiaexcelsa (Mirsen ANSALLA, August 12, 2023)

Figure 2. Irvingiaexcelsa kernels (Mirsen ANSALLA, August 12, 2023)

Determination of Nutrient Content

Moisture Content: Moisture content is the total (measurable) proportion of free water in a food. To determine this, we weighed 40 g of kernels on aluminum foil. We then incubated the samples at 60°C for 5 days, performing repetitive weighings until constant masses were obtained. Moisture content is expressed as a percentage per 100 grams of fresh matter and is calculated as follows (AOAC Standard 950.01, 1990):

$\%Water = (M_f-M_s)/Mf \times 100$

Where: %Water: water content (in %/100 g MF); M_f: mass of fresh kernels (in g);

M_s: mass of dry kernels (in g).

Lipid Content: The lipid content was determined after oil extraction using the Soxhlet method (NF ISO 82 62-3, 2006). Using a hand grinder, we finely ground the dehydrated samples. Into a flask with a mass of M0, placed in a heating mantle, we introduced 200 mL of extraction solvent (N-hexane). A Soxhlet extractor was placed above the flask, into which we inserted a WHATMAN cartridge containing 30 g of ground material (mass M). A condenser filled with cold water was placed on top of the extractor. The flask was then brought to a boil in the heating mantle, thus beginning the extraction. After multiple siphonings, we obtained a mixture of oil and solvent in the flask. Finally, we separated the oil from the solvent using an extractor. After cooling, the flask containing the oil was weighed (M_1). The oil content, expressed as a percentage per 100 grams of dry matter, is calculated using the following formula:

$\%Lipids = (M_1-M_0)/M \times 100$

Where: %Lipids: lipid content (in %/100g dry matter); M: mass of the ground material (in g);

M0: mass of the empty flask (in g); M_1: mass of the flask containing the oil (in g).

Protein Content: The protein content was determined by measuring total nitrogen using the Kjeldahl method. The nitrogenous organic matter in the plant sample was mineralized under heat conditions using concentrated sulfuric acid. The ammonium sulfate resulting from this mineralization was decomposed into ammonia using sodium hydroxide and then titrated with a sulfuric acid solution. We introduced 0.5g of cake (M) into a flask. We added a spatula tip of the catalyst mixture, 10mL of concentrated sulfuric acid (H_2SO_4), and a few glass beads. We then placed the flask on the mineralization ramp and allowed it to mineralize cold for 30 minutes. After these 30 minutes, we started the mineralization device and allowed it to mineralize hot for 2 hours at 415°C. After these 2 hours, we allowed it to cool and added 20mL of distilled water and approximately 30mL of sodium hydroxide (NaOH) at 400g/L until the solution turned brown. This solution was then steam-entrained in a distillation apparatus, and the distillate was collected in an Erlenmeyer flask into which we had previously added 20 mL of 20 g/L boric acid and 3 drops of colored indicator (methyl red mixed with bromocresol green). Distillation continued until 125 mL of distillate was obtained. Finally, we titrated the distillate with a 20 N/20 sulfuric acid solution until the mixture turned pink. The volume of sulfuric acid used during the titration is essential for determining the total nitrogen content. This is calculated using the following formula:

$\%N = (V(H_2SO_4) \times 0.07)/M$

Where: %N: total nitrogen content;

$V(H_2SO_4)$: volume of sulfuric acid used during the titration (in mL);

M: mass of the test sample (in g). Once the total nitrogen content is known, the protein content can be determined. It is expressed as a percentage per 100 grams of dry matter and is calculated using the following formula:

%Protein = %N x 6.25

Where: %Protein: protein content (%/100 g dry matter); 6.25: Conversion factor.

Fiber Content: The fiber content was determined using the Weende method (AOAC, 1990). A mass M equal to 1 g of cake was introduced into a 500 mL flask, followed by 100 mL of 0.255 N sulfuric acid, and the mixture was refluxed for 30 minutes. The residue was vacuum-filtered through a muslin cloth and returned to the flask and treated with 100 mL of 0.313 N NaOH. The mixture was boiled again for 30 minutes before being further filtered. The wet residue was transferred to a previously weighed crucible (M0), which was then placed in an oven at 130°C for 2 hours to dry. After 2 hours, the dry residue was cooled and weighed (M_1). It was then calcined for 30 minutes at 600°C in a muffle furnace, cooled again in a desiccator, and reweighed (M_2).

The crude fiber content, expressed as a percentage per 100 grams of dry matter, is determined by the following formula:

%Crude Fiber = $((M_1-M_o)-(M_2-M_o))/M \times 100$

Where: %Crude Fiber: crude fiber content (in %/100g DM); M0: empty crucible (in g);
M_1: crucible with residue after heating (in g);
M_2: crucible with residue after heating (in g); M: mass of the test sample (in g).

Ash Content: The ash content is a characteristic used to assess the mineral content in the sample. Its determination is carried out by incinerating the raw material in a muffle furnace (standard NFT76.110 September 1981). Consequently, the entire organic fraction is removed by mineralization, leaving only the mineral fraction. Using the balance, we weighed the crucible (M_0) and tared it. We then took a mass M equal to 2g of sample (cake) and placed it in the furnace for 8 hours at 550°C. After the 8 hours, we stopped the furnace and let it rest for 24 hours. Finally, we removed the crucibles from the furnace and weighed them (M_1).

The ash content, expressed as a percentage per 100 grams of dry matter, is calculated using the following formula: %Ash = $(M_1-M_0)/M \times 100$

Where: %Ash: ash content (in %/100g DM); M_0: mass of the empty crucible (in g); M: mass of the test sample (in g); M_1: mass of the crucible containing the ash (in g).

Total Carbohydrate Content: The total carbohydrate content (% Carbohydrates) was estimated relative to the dry mass using the difference method. Thus, the sum of the oil (% Lipids), protein (% Proteins), and ash (% Ash) contents was subtracted from 100. It is expressed as a percentage per 100 grams of dry matter.

% Carbohydrates = 100 – (% Fat + % Protein + % Ash)

Energy Value: Expressed in kilocalories per 100 grams of dry matter, the total energy value (EV) was calculated using the method of Manzi (1999), cited by Diallo Koffi *et al.* in 2015. It is determined using the following formula:

EV (kcal/100g) = (% Carbohydrates x 4) + (% Fat x 9) + (% Protein x 4)

Physicochemical Characterization of the Oil

Acid Number: The acid number of the oil was determined by direct titration of the oil with an alcoholic KOH solution in the presence of phenophthalein (AOAC, standard 969.17, 1997). In an Erlenmeyer flask, a mass m equal to 1 g of oil was mixed with 20 mL of the ether-ethanol mixture and 3 drops of phenophthalein. The mixture was then titrated with a KOH solution of concentration C equal to 0.1 N, using a magnetic stirrer. When a persistent pink color appeared, the titration was stopped and the volume of KOH emitted was recorded (V). The acid value, expressed in milligrams of KOH per gram of fat, is determined by the following formula:

Ia = (56.6 x C x V)/m

Where: Ia: acid value (mg KOH/g); 56.6: molar mass of KOH (in g/mol);

C: KOH concentration (in N); V: volume of KOH used for the titration (in mL);

m: mass of the oil (in g).

Peroxide Value: The peroxide value was determined by neutralizing the amount of iodine corresponding to the amount of peroxides in the oil with sodium thiosulfate. This was performed in two assays (AOAC, standard 965.33, 1997):
For the assay with oil, we poured 1 g of oil (m) into an Erlenmeyer flask. We added 10 mL of chloroform, 15 mL of pure acetic acid, and 1 mL of saturated KI. The mixture was shaken for 1 minute and then kept away from light for 5 minutes. Next, we added 75 mL of distilled water and 3 drops of starch (black spots appear each time a drop falls into the solution). Finally, the mixture was dosed with a 0.01 N sodium thiosulfate solution until the solution became discolored (V_O).
A blank assay (without oil) was performed following the same protocol. The peroxide value, expressed in milliequivalents of active oxygen per kilogram of fat, is determined using the following formula:

$I_p = (V-V_O)/m$

Where: I_p: peroxide value (meq O_2 /Kg); V: volume of sodium thiosulfate used for the oil assay (in mL);

V_0: volume of sodium thiosulfate used for the blank assay (in mL);

m: mass of the oil (in g).

Saponification Index: The saponification index was determined using a back-boiling method. A fatty substance solution was reacted with an excess of alcoholic KOH while hot (reflux boiling). This excess was then measured with a hydrochloric acid solution (AOAC, standard 920.160, 1997). When a fatty substance is brought to a boil in the presence of

KOH, the esters saponify. The KOH reacts with the released fatty acids to form a soap. For the oil assay, we poured 1 g of oil (m) and 20 mL of 0.5 N alcoholic KOH into a flask and refluxed for 1 hour. We then added 3 drops of phenophthalein (the solution turned pinkish-purple) and measured the solution with a 0.5 N HCl solution until the first drop, which discolored the solution. The volume of HCl emitted was recorded (V_1). A blank assay (without oil) was performed following the same protocol. The saponification index, expressed in milligrams of KOH per gram of fat, was determined using the following formula:

$Is = (56.1 \times N (V_0 - V_1))/m$

Where: Is: saponification index (in mg KOH/g); 56.1: molar mass of KOH (in g/mol);

N: KOH concentration (in N); V_1: volume of HCl emitted during the assay with oil (in mL); V_0: volume of HCl emitted during the blank assay (in mL); m: mass of the oil (in g).

Expression of Results: To determine the repeatability of the operations, we used the Gauss-Laplace law. For each analysis (performed in 6 runs), the result is the arithmetic mean of the results obtained during the different runs. Each result is associated with the average standard deviation, which represents the average of the deviations between the different tests relative to the average. Thus, the result is expressed as follows: "average ± standard deviation". This was done using Microsoft Excel Pro 2021 software.

RESULTS AND DISCUSSION

Nutrient Content of Kernels

Water Content: The results obtained for the determination of water content are shown in Table I. The water content of *Irvingiaexcelsa* kernels ranges from 0.59 to 4.07, with an average of 2.89±1.15%. This value is lower than that obtained for *Irvingiagabonensis* kernels (5.5%) by Ladele *et al*. (2015) in Benin. This low content can be explained by the fact that the kernels used had previously been sun-dried to prevent deterioration. This water content is also lower than that obtained for certain peanut varieties (*Arachishypogeae*), which are 5.80% according to Atasie *et al.* (2009); 7.48% according to Ayoola *et al.* (2012), both in Nigeria; 7.13-8.89% according to Eshun *et al.* (2013) in Ghana and 7.58% according to Ossoko (2017) in Congo. Compared to some kernels such as *Borassusaethiopum* studied by Ossoko *et al*. (2019) in Congo, which had a water content of 45.31%, and to some seeds such as *Pachiraglabra*, which had a water content of 7.21% according to the studies of Enzonga *et al.* (2020) in Congo, *Irvingiaexcelsa* kernels are much lower in water content and are more easily stored.

Lipid Content: Oil extraction using the Soxhlet method gave an average yield of 43.97±2.47%, which is not negligible for an NTFP. However, this value is lower than those obtained on the kernels of *Irvingiagabonensis* which are 58 to 68% according to Silou *et al.* (2011) in Congo, 64.24% according to Dahouenon-Ahoussi *et al*. (2012) in Benin, 68.57 to 70.11% according to Ladele *et al.* (2015, 2016) in Benin. Thus the kernels of *Irvingiaexcelsa* are less rich in fat than those of *Irvingiagabonensis*. Also, compared to 47% obtained by Atasie *et al.* (2009); 46.10% obtained by Ayoola *et al.* (2012), both in Nigeria; and 47.43% obtained by Ossoko (2017) in Congo, all on peanut seeds (*Arachishypogeae*), *Irvingiaexcelsa* kernels are less rich in lipids. However, they are richer in fat than *Pachiraglabra* seeds (39.35%) studied by Enzonga *et al.* (2020) and *Borassusaethiopum* kernels (2.4%) studied by Ossoko *et al.* (2019), both in Congo. This value obtained on *Irvingiaexcelsa* kernels (43.97%) shows that they are a good source of lipids and can be used as a raw material in industrial oil production. In addition, at room temperature, the oil obtained coagulates quickly into a white fat, unlike *Irvingiagabonensis* which gives a beige fat (Appendix 3). This suggests that it is also rich in saturated fats like *Irvingiagabonensis*. Thus, the fat from *Irvingiaexcelsa* could prove very useful in the cosmetics industry.

Protein Content: The tests conducted gave us an average protein content of 7.28±1.45%. This value is significantly lower than the 8.71% obtained for *Irvingiagabonensis* kernels by Matos *et al.* (2009) in Congo and Ladele *et al.* (2016) in Benin, but it is higher than that obtained by Ladele *et al.* in 2015 (6.49%), also in Benin. We can therefore say that *Irvingiaexcelsa* kernels are less rich in protein than those of *Irvingiagabonensis.* The protein content of these kernels is also very low compared to the levels obtained by some authors working on certain peanut varieties: 38.61% by Atasie *et al.* (2009); 24.70% by Ayoola *et al.* (2012), both in Nigeria. 23.862-28.88% by Eshun *et al.* (2013) in Ghana and 32.64% by Ossoko (2017) in Congo. It is also lower than that of *Pachiraglabra* seeds (24.71%), studied by Enzonga *et al*. (2020) in Congo. However, it is higher than that of Palmyra palm kernels (*Borassusaethiopum),* which had a content of 5.86% according to studies by Ossoko *et al.* (2019) in Congo. It can therefore be stated that *Irvingiaexcelsa* kernels are not protein-rich and may not be very useful as a protein supplement in diets.

Ash Content: The tests conducted yielded an average content of 3.90±0.14%. This value, which only concerns the overall mineral content, is higher than 2.52% and 2.06%, values obtained on *Irvingiagabonensis* respectively by Ladele *et al.* (2015) in Benin and Matos *et al.* (2009) in Congo. Thus, we deduce that the kernels of Irvingiaexcelsa are richer in mineral elements compared to those of *Irvingiagabonensis*. This mineral content is also higher than that obtained on peanut varieties in Nigeria by Atasie *et al.* in 2009 (3.08%) and Ayoola *et al.* in 2012 (1.48%); and in Ghana by Eshun *et al.* in 2013 (2.45-2.96%). Compared to the mineral content of *Borassusaethiopum* kernels (1.60%) obtained by Ossoko *et al.* (2019) in Congo, *Irvingiaexcelsa* kernels are richer in minerals. However, they contain less minerals than “Manga” peanuts (5.68%) studied by Ossoko in 2017 and *Pachiraglabra* seeds (7.14%) studied by Enzonga *et al.* in 2020, both in Congo.

Carbohydrate Content: Applying the difference method, a carbohydrate content of 44.85% is obtained. This content is higher than those obtained for *Irvingiagabonensis* kernels: 15.77% by Matos *et al.* (2009) in Congo; 14.04% by Ladele *et al.* (2015) in Benin; and 19.20% by Ladele *et al.* (2016), also in Benin. *Irvingiaexcelsa* kernels are therefore richer in carbohydrates than those of *Irvingiagabonensis*. This value (44.85%) is also higher than some values obtained for some peanut varieties: 1.81% by Atasie *et al.* (2009) in Nigeria; 17.41% by Ayoola and Adeyeye (2010) and Ayoola *et al.*

(2012) in Nigeria. 11.54-19.65% by Eshun *et al.* (2013) in Ghana and 17.56% by Ossoko (2017) in Congo. Similarly, Enzonga *et al.* (2020) found carbohydrate contents of 21.59% in *Pachiraglabra* seeds in Congo, which is lower than that obtained in this study. We can therefore say that *Irvingiaexcelsa* kernels are a good source of carbohydrates.

Crude Fiber Content: The fiber contents of *Irvingiaexcelsa* kernels averaged 1.22±0.44%. This value is lower than those obtained for peanut seeds studied in Nigeria by Atasie *et al.* in 2009 (3.70%) and Ayoola *et al.* in 2012 (2.83%); in Ghana by Eshun *et al.* in 2013 (2.69-5.55%) and in Congo by Ossoko in 2017 (5.5%). It is also lower than the 10% fiber content of *Pachiraglabra* seeds studied by Enzonga *et al.* (2020) and the 13.05% fiber content of Palmyra palm (*Borassusaethiopum*) kernels studied by Ossoko *et al.* (2019) in Congo. We can therefore conclude that *Irvingiaexcelsa* kernels are not a good source of fiber.

Energy Value: The energy value obtained is 604.25 Kcal/100g of kernels. Matos *et al.* (2009) in Congo and Dahouenon-Ahoussi *et al.* (2012) in Benin found values of 698 Kcal/100g and 931 Kcal/100g respectively *for Irvingiagabonensis* kernels. Therefore, the energy value of *Irvingiaexcelsa* kernels is lower than that of *Irvingiagabonensis.* This may be explained by the fact that *Irvingiagabonensis* is richer in fat. This value (604.25 Kcal/100g) is, however, higher than that of *Borassusaethiopum* kernels (224.36 Kcal/100g) studied by Ossoko *et al.* (2019) in Congo; *Pachiraglabra* seeds (539.35 Kcal/100g) studied by Enzonga *et al.* (2020) in Congo; and peanut (*Arachishypogaea*) hulls (537.06 Kcal/100g) studied by Eshun *et al.* (2013) in Ghana. We can therefore say that *Irvingiaexcelsa* kernels are a good source of energy.

Physicochemical Characteristics of the Oil

Acid Value: The results obtained for the acid value of *Irvingiaexcelsa* oil gave an average of 2.95±0.26 mg KOH/g of oil, a value higher than 0.90 obtained by Dahouenon-Ahoussi *et al.* (2012) in Benin and 1.96 obtained by Ladele *et al.* (2015) in Benin, both for *Irvingiagabonensis* oil; but significantly lower than 12.94, the value obtained by Matos *et al*. (2009) in Congo for this same oil. Compared to some reference fats such as shea butter with an acid index of 12.80 according to Mégnanou and Diopoh (2008) in Benin, peanut oil with an acid index of 5.99 according to Atasie *et al.* (2009) in Nigeria and 4.28 according to Ossoko (2017) in Congo, *Irvingiaexcelsa* oil has a lower acid index, which means that it has been well preserved.

Peroxide Value: The peroxide value of *Irvingiaexcelsa* oil is 1.92±0.12 meq O_2 per kg on average. This value is equal to that obtained by Matos *et al.* (2009) in Congo on *Irvingiagabonensis* oil (1.9) and significantly higher than 1.25 obtained by Dahouenon-Ahoussi *et al.* (2012) in Benin and 1.44 obtained by Ladele *et al.* (2015) in Benin, also on *Irvingiagabonensis* oil. Compared to the values obtained on peanut oil by Atasie *et al.* (2009) in Nigeria (1.50) and Ossoko (2017) in Congo (2.48); and that obtained by Mégnanou and Diopoh in 2008 in Ivory Coast on shea butter (17.92), *Irvingiaexcelsa* oil has a lower peroxide index, which shows that it is not yet oxidized.

Saponification Index: The saponification index of *Irvingiaexcelsa* oil has an average value of 151. This index is lower than 199, obtained in Congo by Matos *et al.* (2009); 226, obtained in Benin by Dahouenon-Ahoussi *et al.* (2012); and 255, obtained by Ladele *et al*. (2015) in Benin, all on *Irvingiagabonensis* oil. It is also lower compared to the indices obtained on peanut oil by Eshun *et al.* (2013) in Ghana (144.70-208.97) and by Ossoko (2017) in Congo (258.06); and the index obtained for shea butter by Mégnanou and Diopoh (2008) in Ivory Coast (197.24). This index shows that the fat of *Irvingiaexcelsa* can be used in the manufacture of soaps and other cosmetic products.

CONCLUSION AND OUTLOOK

Our study aimed to determine the nutritional value of *Irvingiaexcelsa* kernels, which, unlike that of *Irvingiagabonensis*, remains unknown to date. We conducted physicochemical analyses according to the AOAC standard. *Irvingiaexcelsa* kernels are rich in lipids and carbohydrates, low in protein, fiber, and minerals, but have a good energy value. The oil extracted from these kernels is unoxidized and complies with WHO standards. This oil can be used in the cosmetics industry, particularly in the manufacture of beauty lotions and soaps. The ash content suggests a richness in minerals, essential for the proper functioning of the body. This work should be supplemented by detailed analyses to identify as many biomolecules as possible. In the case of the oil, more in-depth studies must be conducted to identify glycolipids, phospholipids, sphingolipids, isoprenides (carotenes, vitamin A, tocopherols or vitamin E, terpenes, etc.) and determine the fatty acid and glyceride composition, which may be of interest to the food, pharmaceutical, and cosmetic industries. Furthermore, this species is wild and only grows in large forests. Therefore, research should be conducted to explore the possibility of domesticating this tree for industrial oil production.

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