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Research Paper

QUALITY OF *RICINODENDRON HEUDELOTII* (BAIL.) PIERRE EX PAX SEEDS OIL AS AFFECTED BY HEATING

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The effects of heating of *Ricinodendron heudelotii* Bail. oil on quality were investigated. This oil was subjected to microwave heating at three power settings (160, 750 and 900 W) for three different exposure durations (5, 10 and 20 min). The changes in thermal profiles by Differential Scanning Calorimetry (DSC) were studied in comparison to the changes in other physical and chemical characteristics. The physical evaluation of the oil was based on viscosity and ultraviolet absorption whereas chemical evaluation was based on free fatty acid content, peroxide, iodine and anisidine values, fatty acids composition and C 18: 3 / C 16 ratio. The experimental results showed significant changes ($p < 0.05$) in *R. heudelotii* oil quality during heating. The significant increase ($p < 0.05$) of the oil viscosity, sign of thickening, showed that *R. heudelotii* seeds oil is not suitable for use at high temperature.

Keywords: *Ricinodendron heudeloti* Bail oil, Microwave heating, Quality

INTRODUCTION

Ricinodendron heudelotii (*Bail.*) Pierre ex Pax is a tall tree growing wild in African forest. This tree produces fruits with oilseeds called *njansan* in Cameroon and commonly used as spice or soup thickener. With their high oil content (50-61% dw), these seeds are considered as potential raw material for African small scale oil production (Tchiegang *et al.*, 1997).

Eventhough the value of these seeds as a possible source of oil has been reviewed by some workers (Tchiegang *et al.*, 1997; 2003; 2005; Aboubakar Dandjouma *et al.*, 2008), no result has been reported as concerning the use of that oil for cooking.

In fact, during heating oil, numerous chemical reactions such as oxidation occur releasing products which may be hazardous for human health. Due to its diverse advantages compared to other cooking techniques, i.e., savings in time and energy, ease of use, the microwave heating is becoming a major cooking method (Echarte *et al.*, 2003). Microwaves are non-ionizing energy, that can generate heat deep inside the penetrated

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medium by the molecular friction in an electromagnetic field. The heating of food in a microwave oven is caused by interaction of an electromagnetic field with the chemical constituents of foods. These interactions immediately generate heat because of molecular friction and excitation.

Although recent studies concerning the influence of microwave on composition and quality of edible oils and fats (Marinova *et al.*, 2001 ; Vieira and Regitano d'Arce, 2001 ; Tan *et al.*, 2002; Aboubakar Dandjouma *et al.*, 2006) have been reported, at the best of our knowledge, no investigation has been done on how microwave heating affects the quality of *R. heudelotii* oil. This study aimed therefore at investigating the changes in oil *R. heudelotii* physical and chemical properties during heating.

MATERIALS AND METHODS

Materials

Oil was obtained by pressing *R. heudelotii* seeds using the procedure described by Tchiégang *et al.* (2005). The seeds were collected in Mbalmayo in the Centre region of Cameroon.

Microwave Treatments

Microwave heating was performed according to Aboubakar Dandjouma *et al*. (2006). Twenty grams of oil were put into amber bottles, 2 cm internal diameter and placed at equal distances on the turntable rotary plate of the microwave oven. Oil samples were then heated for various periods 5, 10 and 20 min at each power setting (160, 750 and 900 W). The final oil temperatures at various heating times and power settings were measured by inserting a calibrated chromel alumel thermocouple into the oil samples immediately after removal from the microwave oven. These temperature data are presented in Table 1. Analysis of oil was carried out immediately after the heating experiments.

Table 1: Temperatures (°C) of Oil Heated in Microwave Oven at Three Different Power Settings With Different Heating Durations

Heating Durations (min)	Power Settings (W)		
	160	750	900
5	60	120	150
10	90	185	210
20	120	220	250

Standard Chemical and Physical Analyses

AOCS official methods were used to determine acid, anisidine, iodine and peroxide values of the oil samples (AOCS, 1993).

Specific Ultraviolet (UV) Absorbance K_{232} and K_{270} extinction coefficients were calculated from absorption at 232 (conjugated dienes) and 270 nm (conjugated trienes), respectively, with a UV spectrophotometer (Spectronic Genesys 2PC, France), using a 1% solution of oil in cyclohexane (AOCS, 1993).

Oil viscosity measurements were carried out using a Carrimed type Rheometer (Controlled Stress Rheometer) (Rheo, Palaiseau, Paris France) equipped with temperature controller unit, and the results were expressed in mPa.s.

Fatty Acids Compositions

Fatty acids profiles were determined by capillary gas chromatography after transesterification. Fatty Acid Methyl Esters (FAME) were prepared by base catalysis method with 2 N KOH in methanol and analyzed on Perichrom™ 2000 chromatograph equipped with a Flame Ionization Detector (FID) (AOCS, 1993). A capillary column Omega wax 320 (0.32 mm internal diameter, 30

m length and 0.25 µm film thickness) was used at a head column pressure of 10 psi. Helium at 25 ml/s was used as gas carrier. The FID and injector temperatures were both maintained at 260 °C. The injection mode was splitless, and 1 µl of sample was injected with a 10 µl loop. The initial oven temperature was 70 °C and programmed to reach 210 °C at 2 °C/min. The oven was held at this temperature until the analysis was completed. FAME mixtures PUFA N°1, PUFA N°2 and PUFA N°3 (SUPELCO, Supelco Park, Bellefonte, PA, USA) were used as standards for the identification of peaks. The FAME was expressed in relative percentage. The ratios of C18:3 / C16:0 were then calculated.

Thermal Properties

A Perkin – Elmer Differential Scanning Calorimeter (DSC) Pyris 1 model (Perkin-Elmer Corp., Norwalk, USA) was used for the thermal analysis of oil samples. Purified nitrogen at a flow of 20 ml/min was the purge gas for the dry box. The DSC instrument was first calibrated with indium and *n* – dodecane. The DSC melting and crystallization profiles were obtained according to Tan *et al.* (2002). The melting and crystallisation temperatures were obtained by analyzing the profiles with the *Pyris 1* software.

Statistical Analysis

All experiments were done in triplicate, and the results were subjected to an analysis of variance followed by the Duncan's Multiple Range Test using Statgraphics 3.0 Plus software (Statgraphics, 1997)

RESULTS AND DISCUSSION

Chemical Characteristics

The chemical characteristics of unheated and microwave heated *R. heudelotii* oil are shown on Table 2. In this study, acid, iodine, anisidine and peroxide values were employed to assess the level of oil chemical deterioration. In general, microwave heating greatly influenced the oil quality with more abuse observed at high power setting (900 W).

Table 2: Chemical Characteristics of Unheated and Microwave Heated *R. heudelotii* Oil

Power Setting (W)	Heating Duration (min)	Tempe-rature (°C)	Acid Value	Peroxide Value	Anisidine Value	Iodine Value	C18 : 3/C16 : 0
160	5	60	3.26 ± 0.01^{a}	10.43 ± 0.06^{c}	2.04 ± 0.08^{a}	155.60 ± 0.01^{g}	7.27
	10	90	3.33 ± 0.04^{b}	10.85 ± 0.11^{c}	2.28 ± 0.11^{b}	155.53 ± 0.02^{fg}	7.25
	20	120	3.38 ± 0.04^{f}	10.66 ± 0.44^{c}	2.76 ± 0.08^{c}	155.52 ± 0.03^{fg}	7.24
750	5	120	3.46 ± 0.04^{c}	11.97 ± 0.33^{d}	2.23 ± 0.11^{b}	155.33 ± 0.06^{f}	7.24
	10	185	3.76 ± 0.01^{g}	10.29 ± 0.03^{c}	9.56 ± 0.06^{e}	155.11 ± 0.03^{e}	7.01
	20	220	4.80 ± 0.01^{d}	8.57 ± 0.44^{b}	16.20 ± 0.07^{g}	154.09 ± 0.07^{d}	6.91
900	5	150	3.45 ± 0.08^{e}	10.22 ± 0.77^{c}	3.62 ± 0.05^{d}	153.40 ± 0.05^{c}	6.65
	10	210	5.70 ± 0.04^{e}	8.67 ± 0.32^{b}	11.15 ± 0.08^{f}	149.41 ± 0.18^{b}	6.27
	20	250	5.81 ± 0.08^{e}	7.12 ± 0.50^{a}	17.25 ± 0.07^{h}	146.41 ± 0.18^{a}	6.17
Unheated oil			3.16 ± 0.02	6.01 ± 0.14	1.80 ± 0.07	155.61 ± 0.03	7.29

Note: Data within each column with the same superscript are not significantly different (p > 0.05).

Significant increase ($p < 0.05$) was observed in both acid and anisidine values, whereas iodine value exhibited a decrease suggesting the oxidation of unsaturated fatty acids. The changes in oil peroxide value showed an increase for low and medium power settings on one hand and a decrease for heating at high power setting on the other hand. This may be due to the instability of hydroperoxide compounds which at high temperatures rapidly decompose to form secondary oxidation products such as dimers, trimers, ketones, aldehydes and alcohols. Data presented in this study are in agreement with those found in the literature (Tan *et al.*, 2002; Aboubakar Dandjouma *et al.*, 2006). Iodine value of heated oil gradually decreased with increasing power setting and heating durations (Table 2), indicating the reduction of double bounds. In fact, *R. heudelotii* oil is mostly constituted of elaeostearic fatty acid (C18: 3). The presence of three conjugated double bounds makes the oil highly sensible to heating. This observation is confirmed by the reduction of the C18: 3/C16: 0 ratio, with values moving from 7.29 for unheated oil to 6.17 for heated oil (Table 2). Similar observations were made by Tan *et al*. (2002) for microwave heated refined palm olein.

Physical Characteristics

Changes in physical characteristics were monitored by measuring oil absorptivity in ultraviolet light at 232 nm (K_{232}) and 270 nm (K_{270}), and viscosity. A significant increase ($p < 0.05$) was observed in K_{232} values during heating (Table 3) showing the accumulation of peroxide and conjugated dienes in the oil. Similar results were observed for the oil absorptivity at 270 nm indicating the production of trienes and unsaturated ketones or aldehydes due to friction of molecules. Like the absorptivity in ultraviolet

Table 3: Physical Characteristics of Unheated and Microwave Heated *R. heudelotii* Oil

Power Setting	Heating Duration (min)	Temperature (°C)	K_{232}	K_{270}	Viscosity (mPa.S)
160	5	60	1.348 ± 0.003^{a}	0.432 ± 0.001^{a}	65,78 ± 0,04^{a}
	10	90	1.570 ± 0.003^{c}	0.502 ± 0.003^{b}	66,08 ± 0,11^{a}
	20	120	2.178 ± 0.002^{d}	0.757 ± 0.006^{d}	67,31 ± 0,01^{a}
750	5	120	2.216 ± 0.003^{b}	0.539 ± 0.001^{c}	81,4 ± 0,03^{b}
	10	185	3.195 ± 0.002^{f}	0.866 ± 0.005^{e}	89,2 ± 0,07^{b}
	20	220	3.399 ± 0.002^{g}	0.958 ± 0.003^{g}	90,17 ± 0,05^{d}
900	5	150	3.115 ± 0.001^{e}	0.855 ± 0.003^{f}	89,61 ± 0,08^{c}
	10	210	3.208 ± 0.002^{g}	1.624 ± 0.001^{h}	94,19 ± 0,06^{d}
	20	250	3.291 ± 0.002^{h}	1.827 ± 0.001^{i}	98,42 ± 0,11^{e}
Unheated oil			1,191 ± 0,001	0.350 ± 0.002	65.41 ± 0.01

Note: Data within each column with the same superscript are not significantly different ($p > 0.05$).

light, heating lead to a significant increase ($p < 0.05$) of oil viscosity with values varying from 65.41 to 98.42 mPa.s after 20 min heating at high power setting. This change which shows significant structural change may also be due to the presence of elaeostrearic acid which has been shown to be undergo polymerization reactions during heating. In fact, polymerization leads to the formation of high molecular weight compounds via carbon – to – carbon and/or carbon – to-oxygen – to – carbon bridges between fatty acids (Maskan, 2003). The presence of oil oxidation products such as dimers, trimers, polymers, epoxides, alcohols and hydrocarbons could also modify the oil viscosity (Santos *et al.*, 2005). Similar viscosity trends were observed with various heated vegetable oils (Maskan, 2003; Santos *et al.*, 2005; Huang and Sathivel, 2008). Considering the oil viscosity, *R. heudelotii* oil is not suitable for cooking at high temperature or frying, it may be used for salad dressings.

Thermal Properties

As observed with previous characteristics, microwave heating showed a significant influence ($p < 0.05$) on oil thermal properties (Table 4). As the heating temperature increased, both melting and cooling points moved to lower temperatures regardless of the power setting. It has been shown that, the presence of oil oxidation compounds may disturb the rearrangement of different polymorphic forms in oil. As their level increases, these compounds would contribute to changes in DSC cooling and melting profiles. The presence of free fatty acids, partial triglycerides for example tends to shift the melting and crystallisation ranges to lower temperature. The trends observed were noted with other vegetable oils (Tan *et al.*, 2002).

Table 4: Crystallisation and Melting Temperatures of Unheated and Microwave Heated *R. heudelotii* Oil

Power Setting	Heating Duration (min)	Temperature (°C)	Crystallisation Temperature (°C)	Melting Point (°C)
160	5	60	-16.235 ± 0.012^{i}	-31.815 ± 0.019^{i}
	10	90	-16.576 ± 0.006^{h}	-31.998 ± 0.006^{g}
	20	120	-16.974 ± 0.134^{e}	-32.548 ± 0.202^{f}
750	5	120	-16.576 ± 0.006^{g}	-31.842 ± 0.011^{h}
	10	185	-16.744 ± 0.008^{f}	-32.842 ± 0.014^{e}
	20	220	-17.103 ± 0.006^{d}	-33.656 ± 0.006^{c}
900	5	150	-17.325 ± 0.014^{c}	-33.352 ± 0.013^{d}
	10	210	-17.742 ± 0.013^{b}	-35.498 ± 0.008^{b}
	20	250	-17.879 ± 0.032^{a}	-36.347 ± 0.010^{a}
Unheated oil			-16.183 ± 0.095	-31.802 ± 0.006

Note: Data within each column with the same superscript are not significantly different ($p > 0.05$).

CONCLUSION

Microwave heating of *R. heudelotii* oil at various power settings and durations induced changes ($p < 0.05$) in oil quality leading to the formation of free fatty acids, hydroperoxides and secondary oxidation products, decreased level of unsaturated fatty acids and changes in viscosity, melting and crystallisation profiles. Considering the changes observed, we can conclude that *R. heudelotii* oil should not be used for cooking at high temperature or frying. It is just good for salad dressings.

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