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Research Article

Roasting Temperatures, and Durations effect on *Hevea brasiliensis* seed Almonds' Hydrogen Cyanide, and Fatty Acid Contents

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ABSTRACT

Background: Rubber seeds represent weeds to clean after germination. Because their almonds are good sources of energy and polyunsaturated fatty acids, they could be interesting ingredients for animal feeds. However, due to their important hydrogen cyanide contents, they are not used as raw material in poultry feed. **Objectives:** The aim of this study was to remove hydrogen cyanide from rubber seed almonds using a single processing method. **Materials and Methods:** Rubber seed almonds were roasted at 100, 110, 120, 130, and 140 c for 30, 40, 50, and 60 min. Thereafter, they were blended. Twenty (20) g of paste were mineralized and hydrogen cyanide was dosed. Oil samples were then taken for fatty acid profile analysis. **Results:** From the raw material to the roasted product at 140°C for 60 min, hydrogen cyanide was fully removed, decreasing from 633.74 ± 2.86 to 0.0 mg/kg. An increase in polyunsaturated fatty acid content was observed, from 59.17% in the raw material to 69.01% at 140°C for 60 min. The ω-6/ω-3 ratios ranged between 1.95 and 2.26. **Conclusion:** Roasting rubber seed almonds at 140°C for 60 min could be a way to remove their hydrogen cyanide.

Keywords: Fatty acid, Hydrogen Cyanide, Roasting, Rubber Seed Almond, ω-6/ω-3 Ratio.

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INTRODUCTION

Côte d'Ivoire is well known for its cocoa deliveries on international market. But, beside the tandem cocoa-coffee, the country excels in palm oil, pineapple, cashew nuts and *Hevea brasiliensis* rubber latex productions. Of course, in 2019, with 780,000 metric tons produced, Côte d'Ivoire was the leading rubber-producing country in Africa and the sixth largest worldwide (Benoist *et al*., 2020). Alongside important industrial plantations, Côte d'Ivoire's rubber productions are characterized by a predominant and rapidly expanding rural sector, representing approximately 550,000 ha of plantations in 2019. As a result, this production placed Côte d'Ivoire at the top African producer, with almost 70% of Africa's natural rubber latex production (Benoist *et al*., 2020). These plantations produce a lot of rubber seeds, and their germinations are important issues in farms weed cleaning. In fact, apart the small number of grains used for plant production; a large number of seeds are abandoned in the field (Benoist *et al*., 2020). Yet, these grains are seen as good feed sources for animals (Kouassi *et al*., 2020; Oluodo *et al*., 2018). For example (Oluodo *et al*., 2018), indicated that, to be utilized in animals' feed, *Hevea brasiliensis* seed should be boiled and kept a certain period to reduce hydrogen cyanide content. Elsewhere, when the detoxification was achieved (Kouassi *et al*., 2020), mentioned that *Hevea brasiliensis* seed meal improved guinea fowl egg yolk freshness from 81.1 with the control diet to 86.5. Also, fatty acid analyses revealed that, ω-3 content was increased from 2.11% with the control to 3.69% with *Hevea brasiliensis* seed meal enriched diet (Kouassi *et al*., 2020). In the aim to reduce rubber seed oil hydrogen cyanide content (Annisa *et al*., 2020), heated the oil. Alongside hydrogen-cyanide removal, the heat reduced the saturated fatty acid content from 22.81 to 17.79%, increased unsaturated fatty acid from 75.94 to 80.88%. Most importantly, hydrogen cyanide content was reduced by 95% (Annisa *et al*., 2020). Also, for the same purpose, Das and Samanta Das and Samanta (2020) used three treatment methods. Firstly, they soaked the seed overnight. Secondly, they boiled the seed for 1 hr. Finaly, in an oven, they dried the seed at 100°C during 60 min. After all, the samples were stored for 21 days, and Hydrogen Cyanide (HCN) contents were monitored weekly (Das and Samanta, 2020). Though boiling was more effective on

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reducing HCN content after 0, 7, 14, and 21 storing days (Das and Samanta, 2020), the present test hypothesis was "roasting at different temperatures and different durations could allow a new approach for hydrogen cyanide removal." So, the essay aimed to assess the tandem roasting temperatures and durations effect on rubber seed almonds HCN contents, and the derived oils' fatty acid contents.

MATERIALS AND METHODS

In September 2024, some rubber grains were collected in a rural plantation in Daloa region in Côte d'Ivoire. Then, they were transported to the laboratory of Animal Science, at National Polytechnic Institute Felix Houphouët Boigny (INP-HB), Yamoussoukro, Côte d'Ivoire.

Roasting

The rubber tree (*Hevea brasiliensis*) grains were shelled. Then, samples of 180 g each of almonds were weighed, placed in an oven and roasted at different temperatures and durations. Then, the samples were roasted at 100, 110, 120, 130 and 140°C, during 30, 40, 50, 60 and 70 min (Table 1). A sample was kept untreated. The oven (Biobase, China) technical data were 1,500 W power, 220 V, and 50 Hz for the frequency. For each roasting temperature and duration node, the almonds were ground with a blender to get some paste.

Hydrogen Cyanide Dosage

For hydrogen-cyanide determination in almonds (Ocho *et al.*, 2001), approach was lightly modified. So, twenty grams (20 g) of *Hevea brasiliensis* seeds' almonds paste was introduced into 500 mL flask (Pyrex borosilicate glass, Germany), to which 150 ml distilled water were added. The mixture was macerated for 3 hr at room temperature, around 25.5°C, on a stirring plate set at 1200 rotations per minute. A magnetic bar was immersed in the mixture. The bottle was tightly closed with a clean aluminium paper. Next, the macerate was transferred to a second 500 mL flask. The first flask was rinsed with 50 ml distilled water, which was added to the second flask. Altogether, 200 mL mixture was distilled on a heat calotte (Electromantle, United Kingdom) set at 450°C. During the distillation, flask bottom blackened because the starch contained in the almonds was burning. For each distillation, when 100 mL of distillated solution was collected, the distillation was stopped. Two distillates of 100 mL each were collected for each sample. Finally, the two 100 ml distillates were mixed, homogenized and divided into 4 parts of 50 mL each (n=4).

In preparation for the titrations, 10 mL of 0.025 g/mL Sodium Hydroxide (NaOH) solution was added into 100-mL beaker (Equation 1). In the aim to mark Cyanide Ions (CN^-) titration end, 4 mL of 5% Potassium Iodide (KI) solution was added to serve as a colour indicator (Equation 2) in a bottle containing the 50-mL of distillate. Next, 10 mL of NaOH was added to the 50-mL distillate. The titration was performed using a silver-nitrate solution ($AgNO_3$, 0.02 N, Equation 3). During the titration, the cyanide ions (CN^-, Equation 4) combine with silver ions (Ag^+) to form a silver cyanide precipitate AgCN (Equation 5). The end of CN^- sequestration by Ag^+ is marked by the appearance of an opalescent colour in the solution. This opalescence indicates that all CN^- ions have reacted, and Ag^+ ions combine with the iodide (I^-) ions (Equation 6). The titrations were repeated four (4) times for each sample.

$$NaOH \xrightarrow{yields} Na^+ + OH^- \quad (1)$$

$$KI \xrightarrow{yields} K^+ + I^- \text{ Eq.2, I- is used as indicator, when all CN- ions are sequestered.}$$

$$AgNO_3 \xrightarrow{yields} Ag^+ + NO_3^- \quad (3)$$

$$HCN \xrightarrow{yields} H^+ + CN^- \quad (4)$$

$$CN^- + Ag^+ \xrightarrow{yields} AgCN \quad (5)$$

$$I^- + Ag^+ \xrightarrow{yields} AgI \quad (6)$$

The hydrogen cyanide is very volatile. So, when the half of the macerate volume is distilled, we can assume that all the cyanide remaining after roasting is collected in the first 100 mL distillate. Moreover, during acid-base titration (Figure 1), at the saturation point, the number of Ag moles CN ones that reacted were equal (Equation 7).

$$n_{Ag^+} = n_{CN^-} = n_{HCN} = \frac{1}{1000} * [AgNO_3]_{\frac{mol}{L}} * Vol(AgNO_3)_L \quad (7)$$

So, the derived hydrogen-cyanide mass was computed with the Equation 8. Because all the hydrogen cyanide was assumed to be in the 100-mL distillate, we could assess the hydrogen-cyanide mass per gram of macerates *Hevea brasiliensis* paste.

$$m_{HCN} = n_{HCN} * M_{HCN} = 54.0506 * 10^{-2}\ mg * Vol(AgNO_3)_L \quad (8)$$

Due to HCN high volatility, we assumed that HCN contained in 20 g *Hevea brasiliensis* almond paste was collected in 100 mL distillate. So, the relative product concentration was collecting 50 mL had 10 g equivalent almond paste mater (m_{Hb}) (Equations 9.0, Equation 9.1). Finally, we converted HCN mass to a gram of distilled material (Equation 10).

$$[m_{HCN/paste}] = \frac{20}{100} g/mL = \frac{1}{5} g/mL \quad \text{Eq.9.0 } \textit{Hevea brasiliensis} \text{ mater concentration in 100 mL distillate}$$

$$m_{HCN} = \frac{1}{5} g/mL * 50\ mL = 10g \quad \text{Eq.9.1 } \textit{Hevea brasiliensis} \text{ mater mass in 50 mL distillate}$$

$$m_{HCN} = \frac{10^{-0} * 04.0506}{10\ g} mg * Vol(AgNO_3)_L = 0.0540506 \frac{mg}{g} * Vol(AgNO_3)_L \quad (10)$$

Fatty Acid Contents

The fat was extracted, methylated, and fatty acids were analysed by chromatographic analysis.

Lipid Dosage

Lipid determination was carried out according to Folch *et al.* (1957), with 2:1 (vol/vol) dichloromethane -methanol. Then, the extraction was carried out using 10 g sample of each fresh sample homogenized using the Ultra-Turrax at a speed of 4,000 r.p.m., in 50 mL of the solvent. After 3 min homogenization, the whole sample was vacuum filtered, using a Millipore filtration device connected to a compressor. This operation was repeated three times to completely deplete the sample of its lipid components. Next, the solvent mixture containing the lipids and the water from the meat were placed in a flask for Rotavapor separation. The flask' residual contents were washed with 6 mL solvent mixture and 3 mL NaCl solution at 30.5 g/L concentration, then, centrifuged for 20 min at 4,000 r.p.m. The upper phase, composed by water and methanol, containing 40% impurities, was removed using a transfer pipette, while the lower phase, containing the lipids soaked in dichloromethane, was collected in a weighed flask. The solvent was removed using a rotavapour. After the evaporation, thigh muscle lipid quantities were determined by weighing, after drying the flasks. They were then recovered with 1 mL of ethanol, and stored at -20°C until analysis.

Methylation

Following Ichihara and Fukubayashi (2010) method, the methylation began with the reagent R (refrigerator-stable) preparation. The reagent was made by 9.7 mL concentrated Hydrochloric Acid (HCl) (35% wt/wt) diluted in 41.5 mL methanol. Next, 100 µL of each lipid sample to be methylated was added to 0.20 mL toluene, 1.50 mL methanol, and 0.30 mL reagent R in screw-top test tubes. The mixture was homogenized by vortexing for 1 min, and then heated in a water bath at 100°C for 1 hr. After cooling, 2 mL hexane and 2 mL distilled water were added to extract the methyl esters in the upper hexane phase. These were recovered with a transfer pipette, and stored at -20°C until analysis.

Chromatographic Analysis

Fatty Acid Methyl Ester profiles (FAMEs) were determined using an Agilent (Santa Clara, CA, United States) 6,890-N chromatograph, equipped with a DB5- M. S. capillary column (5% phenyl; 95% dimethylpolysiloxane), 30-m × 0.25 mm internal diameter, with 0.25-µm film thickness of the stationary phase. It is coupled to Quattro microTM (GC), Micromass, mass spectrometer equipped with an electron impact source (Ichihara and Fukubayashi, 2010; Kouassi *et al.*, 2020). Helium is used as the carrier gas (1 mL/min). Initially, the furnace temperature is isothermally maintained at 40°C for 6 min, then the thermal gradient of the furnace used is from 40 to 60°C at 1°C/min, 60-140°C at 2°C/min, then 140-240°C at 12°C/min, where the temperature is kept constant for 45 min. Injection is split with a ratio of 1:10. Injector with autosampler and detector temperatures were set at 250 and 230°C, respectively (Al-Madhagy *et al.*, 2023). FAMEs were identified by considering the retention time of each compound on the column under consideration, provided by spectral libraries (Al-Madhagy *et al.*, 2023). Fatty acids were expressed as identified fatty acid in grams per 100 g of matter (Equation 11).

$$C(\%)=\frac{A \times V \times 10 \times F}{Q} x100 \quad (11)$$

Where

C: fatty-acid concentration in sample (g/100 g), (10) conversion factor from 100 to 1,000 g (kg),

A: fatty-acid concentration in the extract (g/mL), V: final volume (mL), Q: sample weight (g),

F: dilution factor.

Statistical Analysis

The statistical analyses were done by using XLSTAT 2014/5/3 software. An analysis of variance was performed on hydrogen cyanides parameters. Thereafter, the Least-Square means (LSD) were separated according to Newman-Keuls (SNK) multiple range tests in 95% confidence interval (α=5%). For hydrogen cyanide content evaluation, 4 samples of 50 ml each were titrated (n=4). Concerning the fatty acid profile, a quality test has been run. So, only one test was performed per sample (n=1).

RESULTS AND DISCUSSION

The analyses assessed the roasting temperatures and durations' effect on the rubber seed almonds' HCN, and fatty acid contents. Elsewhere, because of its important Omega-3 (ω-3) fatty acid contents, linseeds are the nutritional reference in Europe on many aspects (OJEU, 2022). According to Al Madhagy *et al.* (2023), these grains are good antioxidant sources. Moreover, their oil is efficient for anticancer, anti-osteoporosis, anti-inflammatory, and antibacterial activities (Al-Madhagy *et al.*, 2023).

Roasting Temperatures (°C) and Durations (min) Effect on Hydrogen Cyanide Contents

According to Aranguri-Llerena and Siche (2020), the main cyanogenic glucoside compound in plants is Linamarin (Eq.12). Looking at rubber seed almond, after its maturation, the Linamarase enzyme is naturally activated because of the almond moisture (Aranguri-Llerena and Siche, 2020). Instead of Linamarase enzyme, Pirselova and Jakubcinova (2025) said that the natural degradation was due to enzyme β-glucosidase. Moreover, both authors announced that the first step of this degradation result is a cyanohydrin component and a sugar (Aranguri-Llerena and Siche, 2020; Piršelová and Jakubčinová,

Table 1: Nodes of roasting temperatures (°C) and durations (min).

		Roasting temperatures (°C)				
		100	110	120	130	140
Roasting durations (min)	30	100°C/30 min	110°C/30 min	120°C/30 min	130°C/30 min	140°C/30 min
	40	100°C/40 min	110°C/40 min	120°C/40 min	130°C/40 min	140°C/40 min
	50	100°C/50 min	110°C/50 min	120°C/50 min	130°C/50 min	140°C/50 min
	60	100°C/60 min	110°C/60 min	120°C/60 min	130°C/60 min	140°C/60 min
	70	100°C/70 min	110°C/70 min	120°C/70 min	130°C/70 min	140°C/70 min

2025). Under the heat during the roasting process, the linamarin decomposition was accelerated, and the essential gas released into the air was HCN (Equation 13). All the ovens were equipped with rotative systems for air evacuation, while kipping inside a constant temperature. So, during the mineralization process, because the balloons were well closed, the remaining linamarin was decomposed into acetone cyanohydrin, and furthermore into acetone and HCN molecules in solution as H^+ and CN^-. Finally, these remaining CN^- were dosed with Ag^+ as mentioned on Equations 4 and 5.

$$Linamarin\ (C_{10}H_{17}NO_6) + H_2O \xrightarrow{Linamarase} Glucose\ (C_6H_{12}O_6) + Acetone\ cyanohydrin\ (C_4H_7NO) \quad \text{Eq. (12)}$$

$$Acetone\ cyanohydrin\ (C_4H_7NO) \xrightarrow{High\ temperature} Acetone(C_3H_6O) + HCN \quad \text{Eq. (13)}$$

After drying rubber seed almonds at 70°C during 48 hr in ovens (Ocho *et al.*, 2001), reported that the seed almonds had between 25 and 32 g of humidity for 100 g on dry matter basis. In these conditions, the seeds' HCN contents were between 270.9 and 276.2 mg for 100 g of fresh matter (Ocho *et al.*, 2001). Similarly, Yang *et al.* (2021) announced 29.22% for rubber seed almonds moisture content, on wet weight basis. So, rubber seed almonds contain an important moisture.

The untreated rubber seed almonds had 633.74 ± 2.86 mg of HCN per kilogram on fresh matter (Figure 2). The heat treatment drastically reduced HCN contents. Generally, two tendencies were observed. For example, roasting at 100, 110, 120 and 130°C, during 30, 40, 50, 60 and 70 min could not decrease HCN content below 35 mg/kg. Though, roasting at 130°C led to an important decreased in HCN content compared to 110 and 120°C, it was not good. OJEU (2022) reported that, for unprocessed whole, ground, milled, cracked, chopped almonds placed on the market for the final consumer, HCN content upper limit could be 35 mg/kg of product. So, roasting at 100, 110, 120 and 130°C was not a good idea. However, roasting at 140°C showed promising results at 60 min (Figure 2). Of course, HCN was fully removed, because during the dosage process, the first Ag^+ drop led to the opalescent precipitated product. Elsewhere, when Annisa *et al.*, (2020). Heated rubber seed oil at 100°C during 60 min, they reduced HCN content by 95%.

Looking at different roasting durations, at 60 min, HCN content dropped from 163.50 to 109.45, and reached 0.0 mg/kg at 120, 130 and 140°C treatments, respectively ($p < 0.0001$). So, the objective has been achieved at node 140°C/60 min. For example Park *et al.* (2024), mentioned that after an assessment among linseed products sold in South Korea, their HCN content were between 1,659.73 and 4,655.45 µg/kg. Generally, HCN contents in many linseed products were above casava chips HCN content, which was around 2,099.59 µg/kg (Park *et al.*, 2024). Regarding OJEU (2022) guidelines, roasting rubber seed almonds at 140°C during 60 min led to a good result. In fact, HCN was completely removed. Das and Samanta (Das and Samanta, 2020) work reduced HCN content in rubber seed almonds. But, after conserving the derived products for 21 days, soaked, boiled, and oven dried at 100°C during 60 min, HCN contents were still above 35 mg/kg (Das and Samanta, 2020)

Roasting approach was tested by Matho *et al.* (2021), when they roasted peeled rubber seeds in a metallic frying pan for 45 min. HCN content was reduced by 50.82%, from 87.34 to 44.39 mg/kg (Matho *et al.*, 2021). Dealing with the metallic frying pan necessitated 45 min, this operation was an important time gain, though there was not a control on the roasting temperature. While boiling was followed by drying under the sun and soaking needed hours (Matho *et al.*, 2021). Surely, these three treatments are time consuming, compared to roasting. Likewise, Yuniar *et al.* (2024) soaked rubber seed almonds for 4 days in water containing some rice husk charcoal at 1/1 ratio. That way, they reached HCN content between 6.75 and 0.54 mg/kg (Yuniar *et al.*, 2024). Nevertheless, the final product quality was subjected to a cleaning system. With a high concern, Lehrich and Adiche (2023) mentioned HCN gas importance in plastic manufacturing such the synthetic fibres, herbicides, and many other products. Because of their importance, HCN is industrially produced (Lehrich and Adiche, 2023) (Equation 14). Thus, an industrial roasting system of rubber seed almonds could be an additional way to get HCN gas.

$$CH_4 + NH_3 + 1.5O_2 \rightarrow HCN + 3H_2O \quad (14)$$

Hevea brasiliensis Seed Almonds' Fatty Acids

Many changes were observed from the raw material to the products at 140°C/60 min (Table 2). Alongside the hydrogen-cyanide

removals from the rubber seeds' almonds raw material, important Unsaturated Fatty Acids (UFA) were synthetized. For example, from 17.76% on the node 25.5°C/0 min, the total saturated fatty acid contents decreased to 11.40% on node 140°C/60 min (Tables 2 and 3), it means a loss of 6.36%. This decrease was supported by palmitic fatty acid (C16:0) for 3.14% and stearic fatty acid for 3.07%. Hence, with 6.21% decrease, these two saturated fatty acids represented 97.64% of the total reduction (Table 3). Similarly, the monounsaturated fatty acids decreased by 1.41%, and this decrease was mainly due to oleic fatty acid (C18:1) loss for 1.24%. Important to realize, oleic fatty acid decrease proportion represented 87.94% of the overall monounsaturated fatty acids reduction.

According to Lavoisier, during chemical reactions, nothing is created, nothing is lost, everything is transformed. Here, the reconversion led to polyunsaturated fatty acids synthesis. Alternatively, polyunsaturated fatty acid contents increased from 59.17 to 69.01%. So, +9.84%, gain was observed, from the raw material to the node 140°C/60 min (Table 3). It could be concluded that, roasting allowed 2 main changes. For sure, roasting removed hydrogen cyanide from the rubber seed almonds. Better, it improved the final product nutritional quality, by increasing the unsaturated fatty acids' proportion. For example, palmitic acid (C16:0) decreased from 9.32 to 6.18%, -3.84%. At the same moment, ω-3 fatty acid sources such as linolenic acid (C18:3), eicosapentaenoic acid (C20:5), and Docosapentenoic (C22:5), importantly increased from 19.9 to 22.43%, +2.53%. On the negative side, the most gain came from linoleic (C18:2), ω-6 fatty acid, from 39.13 to 46.42%. Globally, ω-3 fatty acid contents moved from 20.04 to 22.59%, representing 25.91% overall increase among polyunsaturated fatty acids. Conversely, linoleic acid (C18:2), ω-6 fatty acid, increase represented 74.08%, among the total polyunsaturated fatty acids. So, during the heat treatment, when one ω-3 molecule was synthetized, three ω-6 molecules were made, leading to 3:1 ratio (Equation 15).

$$\frac{\Delta\omega 6}{\Delta\omega 3} = \frac{74.08}{25.91} = 2.86 \simeq 3:1 \quad (15)$$

Reactions Interpretation

It should be kept in memory that Linamarin split provides glucose ($C_6H_{12}O_6$) and acetone cyanohydrin (C_4H_7NO) (Eq.8). Due to the heat, in a humid atmosphere, combinations between C16:0 with glucose, could lead to Docosapentenoic (C22:5) or Docosahexanoic (C22:6) fatty acids synthesis (Equations16 and 17). Likewise, a combination between C18:0 and C_4H_7NO could allow similar results (Equations18 and 19). Moreover, if Myristic fatty acid (C14:0) combines with glucose molecules, the result may lead to Eicosapentaenoic (C20:5) synthesis (Equation 20). These prospective reactions are in accordance with Lalmana and Bagley (2002) observations. Indeed, they concluded that stearic

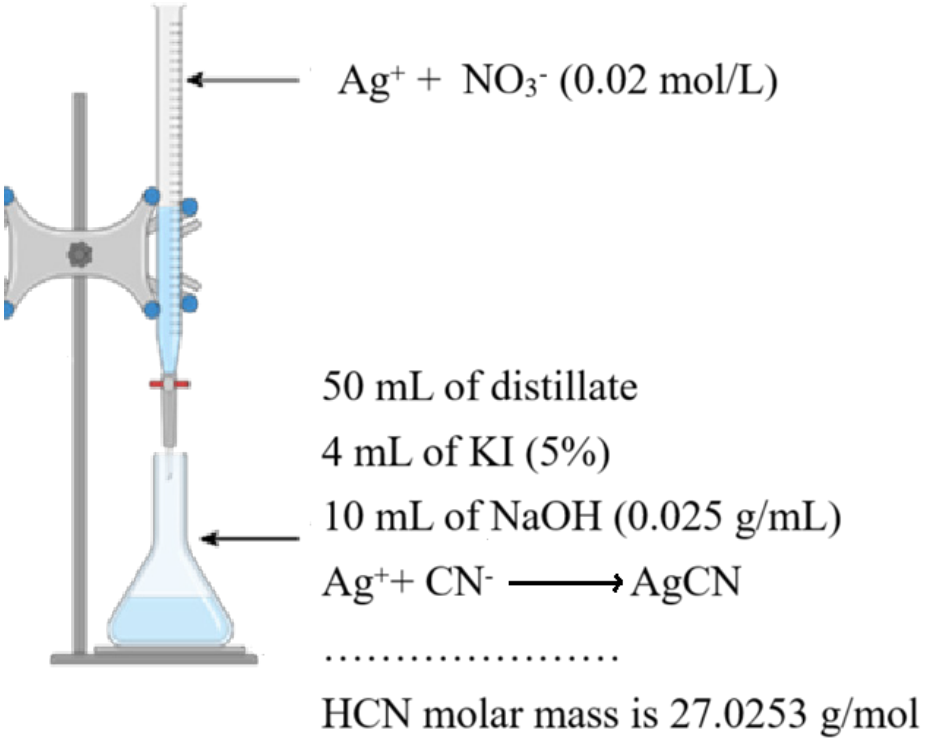

Figure 1: Acid-base titration between Ag+ and CN-.

Table 2: Roasting temperature (°C) and time (min) effect on *Hevea brasiliensis* almonds' fatty acids (%).

	Roasting temperature (°C)/Roasting duration (min)												
Fatty acids	25.5°C/0	100°C/30	110°C/40	110°C/50	120°C/40	120°C/50	120°C/60	130°C/50	130°C/60	130°C/70	140°C/50	140°C/60	140°C/70
C14:0-myristic	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C16:0 palmitic	9.32	9.25	8.91	8.72	8.57	8.64	8.43	8.38	8.41	7.47	7.21	6.18	5.48
C18:0-stearic	8.23	7.78	7.92	7.86	8.09	7.37	7.02	6.49	6.21	5.71	5.55	5.16	4.71
C24:0-lignoceric	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.06	0.06	0.08
SFA	17.76	17.03	16.83	16.58	16.66	16.01	15.45	14.87	14.62	13.25	12.82	11.40	10.27
C14:1. ω-5 myristoleic	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C16:1. ω-7 palmitoleic	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C18:1. ω-9 oleic	23.02	22.49	21.96	21.03	20.80	20.84	20.89	20.90	20.94	21.06	21.19	21.78	22.68
C24:1. ω-9 Nervonic	0.04	0.04	0.01	0.01	0.01	0.01	0.02	0.02	0.07	0.07	0.05	0.05	0.04
MUFA	23.24	22.53	21.97	21.04	20.81	20.85	20.91	20.92	21.01	21.13	21.24	21.83	22.72
C18:3. ω-3 linolenic	19.90	19.66	19.46	19.08	19.22	19.07	18.46	18.88	18.86	19.59	19.70	20.44	20.55
C20:5. ω-3 eicosapentaenoic	0.00	0.00	0.00	1.00	0.89	0.94	1.00	1.00	1.30	1.36	1.59	1.60	1.75
C22:5. ω-3 Docosapentenoic	0.00	0.00	0.00	0.00	0.42	0.42	0.43	0.43	0.45	0.44	0.38	0.39	0.38
C22:6. ω-3 docosahexanoic	0.14	0.14	0.08	0.08	0.09	0.09	0.08	0.08	0.23	0.24	0.16	0.16	0.25
Total ω-3	20.04	19.80	19.54	20.16	20.62	20.52	19.97	20.39	20.84	21.63	21.83	22.59	22.93
C18:2 ω-6 linoleic	39.13	40.76	41.80	43.32	43.43	44.19	45.17	45.39	45.55	46.15	46.31	46.42	46.58
PUFA	59.17	60.56	61.34	63.48	64.05	64.71	65.14	65.78	66.39	67.78	68.14	69.01	69.51
UFA	82.41	83.09	83.30	84.51	84.86	85.56	86.05	86.70	87.40	88.90	89.38	90.84	92.23
PUFA/MUFA	2.55	2.69	2.79	3.02	3.08	3.10	3.12	3.14	3.16	3.21	3.21	3.16	3.06
ω-6/ω-3	1.95	2.06	2.14	2.15	2.11	2.15	2.26	2.23	2.19	2.13	2.12	2.06	2.03
UFA/SFA	4.64	4.88	4.95	5.10	5.09	5.34	5.57	5.83	5.98	6.71	6.97	7.97	8.98

Abbreviations: **MUFA:** Monounsaturated Fatty Acids; **PUFA:** Polyunsaturated Fatty Acids; **SFA:** Saturated Fatty Acids; **UFA:** Unsaturated Fatty Acids; **ω-3:** OMEGA-3; **ω-6:** Omega-6; **ω-9:** Omega-9 (n=1).

acid, oleic acid, and linoleic acid react with glucoses molecules (Lalmana and Bagley, 2002).

$$C16{:}0\ [CH_3(CH_2)_{14}COOH] + Glucose[O = CH(CHOH)_4CH_2OH] \rightarrow C22{:}5[CH_3(CH_2CH{=}CH)_5(CH_2)_5COOH]+\beta \quad \text{(Eq.16)}$$

$$C16{:}0\ [CH_3(CH_2)_{14}COOH] + Glucose\ [O = CH(CHOH)_4CH_2OH] \rightarrow C22{:}6[CH_3(CH_2CH = CH)_6(CH_2)_2COOH] +\varphi \quad \text{(Eq.17)}$$

$$C18{:}0\ [CH_3(CH_2)14\ COOH]+a.cyanohydrin\ [HOC(CH_3)_2 C{\equiv}N] \rightarrow C22{:}5[CH_3\ (CH_2\ CH{=}CH)_5\ (CH_2)_5\ COOH]+\chi \quad \text{(Eq.18)}$$

$$C18{:}0\ [CH_3\ (CH_2)_{14}\ COOH]+a.cyanohydrin\ [HOC(CH_3)_2 CN] \rightarrow C22{:}6[CH_3\ (CH_2\ CH{=}CH)_6\ (CH_2)_2\ COOH]+\pi \quad \text{(Eq.19)}$$

$$C14{:}0\ [CH_3\ (CH_2)_{12}\ COOH]+Glucose\ [O{=}CH(CHOH)_4\ CH_2 OH] \rightarrow C20{:}5[CH_3\ (CH_2\ CH{=}CH)_5\ (CH_2)_3\ COOH]+\gamma \quad \text{(Eq.20)}$$

Looking at C18:0 and C18:1 degradation for C18:1, C18:2 and C18:3 syntheses, Karasuta et al. (2021) mentioned that some dehydrogenations are required. The loss of "H" conduct to double bound formation between "C=C" carbons. So, during the roasting treatment, progressively, C18:0, and C18:1 fatty acid decreased Karasuta *et al.*, (2021). Charuwat *et al.* (2018) mentioned that, during a hydrolysis at 160°C during 8 hr, long chain fatty acids such as C18:0, C18:1, and C18:2 led to short chain acid. For example, they observed the occurrence of acetic ($C_2H_4O_2$), heptanoic ($C_7H_{14}O_2$), and caproic ($C_6H_{12}O_2$) acids (Charuwat *et al.*, 2018). Under heat, in humid atmosphere, while some long chains fatty acids are breaking, some are forming by combining with glucose (Lalman and Bagley, 2002). Already, Simopoulos and DiNicolantonio (2016) warned that, the energy gained from ω-6 does not have the same effect in human body as the one received from ω-3 source. So that, they promoted the concept "a calorie is not a calorie" looking at the source of this calorie. Because ω-6 fatty acids have depressive actions in human body, they should be well imbalanced with ω-3 fatty acids. Simopoulos and

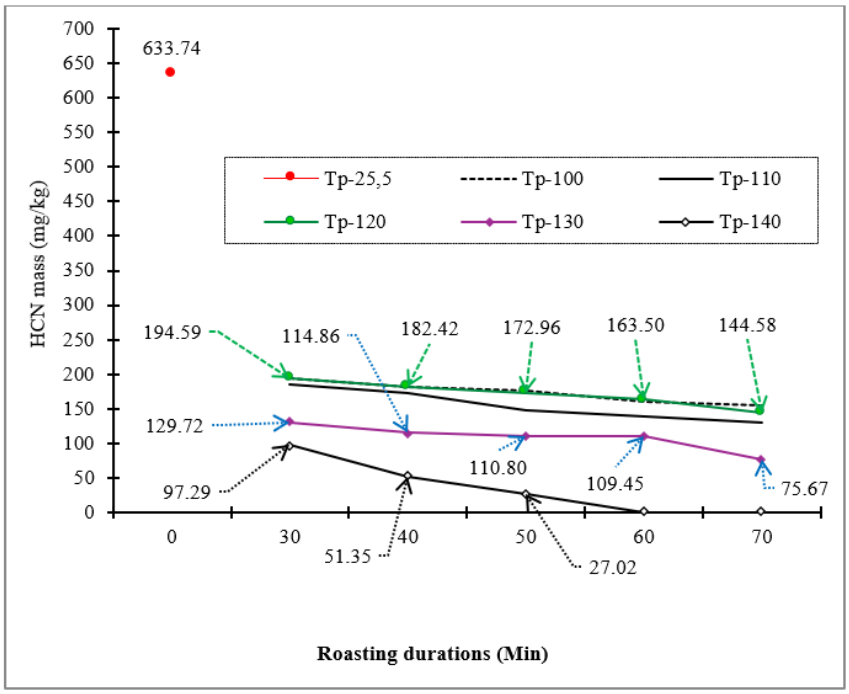

Figure 2: Roasting temperatures (°C) and durations (min) effect on hydrogen cyanide (HCN) contents (n=4), δ=2.86.

Table 3: Changes in fatty acids' contents from 25.5 to 140°C/60 min.

	Temperature/duration		Changes	%Changes
	25.5°C/0 min	140°C/60 min		
C14:0-myristic	0.21	0.00	-0.21	3.30
C16:0-palmitic	9.32	6.18	-3.14	49.37
C18:0-stearic	8.23	5.16	-3.07	48.27
C24:0-lignoceric	0.00	0.06	+0.06	-0.94
SFA	17.76	11.40	-6.36	100
C14:1 ω-5-myristoleic	0.13	0.00	-0.13	9.22
C16:1 ω-7-palmitoleic	0.05	0.00	-0.05	3.55
C18:1 ω-9-oleic	23.02	21.78	-1.24	87.94
C24:1. ω-9-Nervonic	0.04	0.05	+0.01	-0.71
MUFA	23.24	21.83	-1.41	100
C18:2 ω-6-linoleic	39.13	46.42	+7.29	74.08
C18:3 ω-3-linolenic	19.90	20.44	+0.54	5.49
C20:5 ω-3-eicosapentaenoic	0.00	1.60	+1.60	16.26
C22:5 ω-3-Docosapentenoic	0.00	0.39	+0.39	3.96
C22:6 ω-3-docosahexanoic	0.14	0.16	+0.02	0.20
Total ω-3	20.04	22.59	+2.55	
PUFA	59.17	69.01	+9.84	100
UFA	82.41	90.84	+8.43	
PUFA/MUFA	2.55	3.16	+0.61	
ω-6/ω-3	1.95	2.06	+0.11	
UFA/SFA	4.64	7.97	+3.33	

Abbreviations: **MUFA:** Monounsaturated Fatty Acids; **PUFA:** Polyunsaturated Fatty Acids; **SFA:** Saturated Fatty Acids; **UFA:** Unsaturated Fatty Acids; **ω-3:** Omega-3; **ω-6:** Omega-6; **ω-9:** Omega-9 (n=1).

DiNicolantonio (2016) concluded that ω-3 fatty acids participate to a decrease in adipose-tissue development and lead to weight loss. In contrary, ω-6 fatty acids increase adipose-tissue synthesis and lead to obesity (Simopoulos and DiNicolantonio, 2016). After examining various effects of ω-6/ω-3 ratios on experiment animals, Simopoulos and DiNicolantonio (2016) indicated that the preferred ratio for an optimal health could be 1:1 or 2:1. This ω-6/ω-3 ratio interval 1:1 to 2:1 was increased, and set to be optimal between 1:1 and 5:1 according to Gonzalez-Becerra *et al.* (2023). Anyhow, high ω-6/ω-3 ratios between 10:1 and 20:1 should be stickily avoided, because they increase the risk of inflammatory diseases and obesity (Gonzalez-Becerra *et al.*, 2023; Simopoulos and DiNicolantonio, 2016). On this final view, roasting rubber seed almonds at 140°C for 60 min could be a good way to make some almonds cake for animal feed. Due to the polyunsaturated proportion, the oil may be good for human nutrition.

CONCLUSION

Because rubber seed almonds are underutilized in Côte d'Ivoire, finding an industrial process to eliminate its almonds' hydrogen cyanide could be very helpful. So, the work consisted in roasting the almonds at different temperatures and durations, in ovens. The promising results revealed that, at 140°C, when *Hevea brasiliensis* seed almonds were roasted during 60 min, their hydrogen cyanide was fully removed. So, instead of many successive treatments, such as boiling or soaking, then drying under the sun, roasting may allow better results in a relative short time. This temperature could be set as a reference, and the experience could be done again at 135, 140, and 145°C for 50, 55, and 60 min. Moreover, the experiment could be set in a roasting rotative system. Perhaps, it could be more efficient than the static one, we used.

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ABBREVIATIONS

HCN: Hydrogen cyanide; **INP-HB:** Institut National Polytechnique Felix Houphouët Boigny; **SFA:** Saturated Fatty Acids; **MUFA:** Monounsaturated Fatty Acids; **PUFA:** Polyunsaturated Fatty Acid; **UFA:** Unsaturated Fatty Acids.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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