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# Physicochemical and Nutritive Characterization of Linoleic Acid-rich Oil from Seeds of *Celosia argentea*

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## ABSTRACT

*Celosia argentea* is annual herbaceous widely used as leafy vegetable in Côte d'Ivoire. In this study, physicochemical and nutritive analysis of this plant seed oil was performed in order to explore its potential applications. Physicochemical properties of extracted oil were as follow: specific gravity (0.92±0.01), refractive index (1.47±0.00), colour lovibond (20.2±0.00), viscosity at 20°C (53.08±0.28 mPas), cloud point (-2.3±0.00°C) acid value (4.68±1.62 mg KOH/g), peroxide value (10.33±0.58 meq $O_2$/kg), iodine value (124.08±1.22 g $I_2$/100g), saponification value (170.17±1.62 mg KOH/g). Biochemical and nutritive analysis have revealed the following assets: impurities (0.016±0.00%), unsaponifiable matter (1.47±0.21%), phosphorus (0.10±0.00 mg/g), vitamin A (0.52±0.01 mg/g) and vitamin E (0.12±0.01 mg/g). Fatty acids profile of *C. argentea* seed oil highlighted linoleic acids as major fatty acid with amount of 49.94±0.01%. All these interesting characteristics should arouse attention for the usage of *C. argentea* seed oil in food and pharmaceutical industries.

**Keywords:** *Celosia argentea*, seed oil, vitamin A, vitamin E, linoleic acid, essential fatty acid

## 1. INTRODUCTION

Many oils and fats for human consumption or for industrial purposes are derived from plant seeds. Indeed, these seeds constitute essential vegetable oil reserves with nutritional, industrial and pharmaceutical importance [1]. Extracted oils from plant seeds are mainly composed of triacylglycerols (95-98%) which are esters of glycerol and complex mixtures (2-5%) of minor compounds [2]. These minor compounds include fat soluble vitamins, pigments such as chlorophylls and carotenoids, phenolic compounds, phospholipids, mono and diacylglycerols and free fatty acids [3].

Fatty acids composition of vegetable oils determines their physicochemical properties and nutritional value [4]. The most common dietary fatty acids have been subdivided into three broad classes which are saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) [5]. Natural PUFA can be divided into 12 families, ranging from double bonds located at the n-1 position to the n-12 and

the most important families for human health and nutrition, are the ω6 (n-6) and ω3 (n-3) families [6]. These families are similar as they both comprise a precursor, namely linoleic acid (LA) for the ω6 and α-linolenic acid (ALA) for the ω3. Linoleic and linolenic acids are essential fatty acids (EFA) for human nutrition because they are unable to be physiologically synthesized. In this respect, diet must cover organism needs [7]. Indeed, linoleic acid is metabolized to arachidonic acid (AA) while α-linolenic acid is metabolized to eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) as active metabolic products for the synthesis of biologically active compounds such as steroid hormones, prostaglandins and leukotrienes [8].

Apart from the leukotrienes and prostaglandins structuring, the optimal ratio of n-6/n-3 of 4:1 or less in human nutrition is important to avoid the development of allergic, inflammatory disorders and cell proliferation [9]. Linoleic acid deficiency is characterized by children growth retardation, skin lesions, dry scaly dermatitis and reproductive failures while cognitive development and visual acuity may be impaired for children receiving inadequate intakes of α-linolenic acid [10].

In view of the cardinal role of EFA in human health and diseases, characterization of the fatty acids composition of oils has become a current focus of lipid research [11]. It is from this perspective that a number of non-conventional oilseeds from several plants of Sub-saharan Africa have been investigated [12]. Therefore, to contribute to non-conventional oils promotion, we have focused our attention on seed oil of *Celosia argentea*, an important tropical plant.

*C. argentea* is annual herbaceous plant which belongs to the order *Amaranthaceae*. In most countries of tropical Africa and particularly in Côte d'Ivoire, leaves of these plants are widely consumed as green vegetables due to their richness in polysaccharides, vitamins and minerals [13]. Based on ethno-botanical practice, this plant was investigated for anti inflammatory, anti- pyretic, anti diabetic, anti bacterial and diuretic properties [14]. To date, there is no report to the best of our knowledge about the physicochemical and nutritive characteristics of oil extracted from this plant seeds. In this paper, we report on the physicochemical and nutritive properties of *Celosia argentea* seed oil in order to promote this non-conventional oilseed.

## 2. MATERIALS AND METHODS

### 2.1 Plant Material

Mature *C. argentea* seeds were collected from market gardening of Abidjan district (Côte d'Ivoire) in June 2012. The plant was identified and authenticated by Professor Ake Assi (Botany Department of Félix Houphouët Boigny University - Abidjan). Voucher specimen (No ABAN10) of the plant was kept in the herbarium of National Center of Agronomic Research (CNRA) of Côte d'Ivoire. Seeds were rinsed thoroughly with distilled water to remove dirt and dried at 40°C for 24 h in an electric oven (Memmert, Germany) [15].

### 2.2 Chemicals

Analytical HPLC grade solvents, standards and reagents were used to perform analysis. Solvents (n-hexane, chloroform, acetic acid, diethyl-ether, ethanol, methanol and n-heptane) were from Merck (Germany). Standards such as fatty acids (palmitic acid, stearic acid, oleic acid, linoleic acid and a-linolenic acid), retinol palmitate (vitamin A), α-tocopherol acetate (vitamin E) and erucic acid were from Sigma-Aldrich (Germany). Wijs reagent was from Prolabo (France).

All other reagents used were of analytical grade.

**2.3 Moisture of Seeds**

Moisture of *Celosia argentea* seeds was determined following the AOAC method [20]

**2.4 Extraction of Seed Oil**

Oil was extracted from 50 g crushed seeds (Laboratory crusher, Culatti, France) with 300 mL of n-hexane at 60°C in a Soxhlet extractor for 7 h. Then the solvent was removed (vacuum-packed) at 40°C with a rotary evaporator (Heidolph, Hei-Vap, Germany). After evaporating, the remaining solvent was removed by drying in oven at 103°C for 2 h. The extracted lipid was weighed to determine the oil content of the seeds. Crude oils were stored at 4°C in air tight brown sterile glass bottles until further use [16].

**2.5 Physicochemical Analysis of Seed Oil**

Specific gravity at 20°C, refractive index at 20°C and specific extinction (232 nm and 270 nm) were carried out following the IUPAC methods [17].

Color and cloud point were determined according to the MPOB methods [18] by using a Lovibond colorimeter (Lico, Labomat, France) and a thermometric system (FP900, Metller Toledo, Switzerland) respectively.

Viscosity was determined at different temperatures (20-80°C) by using a viscometer apparatus (SVM 3000, Anton Paar Gmbh, Austria) equipped with a syringe filled with 1 mL of oilseed sample. Values of viscosities were automatically recorded after temperature programming.

Visible and Near infrared spectrum (NIR) was determined by reading absorbance of oil sample in the range of 400-2500 nm by using a infrared spectrophotometer (Foss liquid analyzer, Denmark) equipped with a software (NIR Vision Spectral Analysis, Model 6500) for data acquisition.

pH value of oil sample was determined at 25°C following a described pH-metric method [19]. 2 mL of oil sample were dissolved in 15 mL of n-hexane. The pH-meter electrode was standardized with buffer solutions (pH 4.0 and 7.0) and then, immersed into the sample to record pH value.

Acid, peroxide, iodine and saponification values were determined by the AOAC methods [20].

**2.6 Biochemical Analysis of Seed Oil**

Unsaponifiable matter content of oil samples was determined following the IUPAC method [17]. Oil sample (5 g) was saponified with 50 mL of 2 N KOH methanolic solution for 1 h. To the resulted mixture, 50 mL of distilled water was added. The unsaponifiable matter was extracted three times with 50 mL of diethyl-ether. Organic fractions were collected, washed three times with 50 mL of distilled water and then dried with sodium sulfate. Diethyl-ether was removed in a rotary evaporator (Heidolph, Hei-Vap, Germany) to recover the unsaponifiable matter which was then weighed.

Moisture, impurities, total fatty matter and total saponifiable matter contents were determined according to the MPOB test methods [18]. For impurities, 20 g of crude oil was mixed with 100 mL of n-hexane. The mixture obtained was then filtered through cellulose filter paper under slight vacuum. The filter paper was dried in the oven at 103°C for 1 h and cooled in the desiccator. The filter paper was finally weighted to determine the insoluble impurities as percentage by mass of crude oil. Total fatty matter and total saponifiable matter were determined in percentage following the formulas:

Total fatty matter (%) = 100 - (moisture + impurities)

Total saponifiable matter (%) = Total fatty matter - Unsaponifiable matter

### 2.7 Nutritional Analysis of Seed Oil

#### 2.7.1 Phosphorus content

Phosphorus content of oil sample was determined following the IUPAC colorimetric method [17]. The test oil portion (5 g) was burned to ashes in the presence of magnesium oxide. The ashes obtained were dissolved in diluted nitric acid solution (65%). Absorbance was then measured at 460 nm using a spectrophotometer (T80+, PG Instruments, England) after adding an aqueous ammonium vanadate solution. A standard curve of phosphorus (1 mg/mL) was used as reference.

#### 2.7.2 Vitamin A and vitamin E contents

Seed Oil sample was previously prepared as following: oil sample (1 g) was diluted in 10 mL of hexane. Thereafter, 200 μL of this mixture was transferred into a screw-capped tube where 800 μL of methanol were added. After being vortex-mixed and centrifuged (3000 g for 5 min), the samples were filtered through a 0.45 μm pore size filter and the overlay was used for high performance liquid chromatography (HPLC) analysis [21]. Separation by HPLC was carried out using a liquid chromatography system (Acquity Waters, USA) equipped with an optical detector TUV system and a BEH $C_{18}$ column (150 × 0.25 mm i.d., 1.7 μm particle size). The injection volume was 10 μL. The mobile phase was methanol-water (98:2, v/v) and the elution was performed at a flow rate of 2 mL/min. The analytical column was kept at 45°C. Vitamin A of oil sample was detected at 325 nm and identified by comparing its retention time with this of authentic standard. Quantification of vitamin A identified in oil sample was done by using a standard curve (concentration versus peak area) of retinol palmitate. Vitamin E of oil sample was detected at 292 nm and identified by comparing its retention time with this of authentic standard. Quantification of vitamin E identified in oil sample was done by using a standard curve (concentration versus peak area) of α-tocopherol acetate. All the data obtained were stored and processed by Empower software (Waters, USA). The contents of vitamin A and E (mg/g) were calculated using the following formula: $0.5 \times C \times V_2 / m \times V_1$

Where, C: concentration of vitamin (μg/mL) obtained by using standard curve of concentration versus peak area; $V_2$: volume (mL) of sample prepared; $V_1$: volume (mL) of sample aliquot used, m: mass (g) of oil sample.

#### 2.7.3 Fatty acids composition

The fatty acids were converted to their methyl esters (FAMEs) as described by the European Communities methods [22]. 0.1 g of oil sample was mixed with 2 mL of n-heptane and 0.2 mL of a methanolic solution of potassium hydroxide (2N). The whole mixture was shaken up for 30 s and allowed to settle for 5 min. The top layer containing the FAMEs was used for gas chromatography (GC) analysis. FAMEs solution (1 μL) containing the internal standard (erucic acid) was injected into a gas chromatograph (Shimadzu, GC-9A, Japan) equipped with a mass spectrometer (MS) and a RTX5 fused silica capillary column (30 m × 0.32 mm i.d. × 0.25 μm film thickness). The carrier gas was helium and the flow rate adjusted to 23 mL/min. Temperatures of detector and injector were 250°C. The initial column temperature was fixed to 100°C and programmed to increase by 5°C per min

intervals until 220°C and, kept for 10 min at this temperature. The fatty acid methyl esters peaks were identified by comparing their retention times with those of standards. After adjusting areas with the internal standard (erucic acid), the content of each fatty acid was calculated as follow: area of the fatty acid/areas of total fatty acids in the oil sample × 100 (%).

### 2.8 Statistical Analysis

In the present experiment each test for the sample was analyzed in triplicate. Data were performed by using StatPlus 2009 (Analystsoft Inc) software and values were expressed as means ± standard deviation (SD).

## 3. RESULTS AND DISCUSSION

### 3.1 Moisture Content of Seeds and Oil Yield

The moisture content of *Celosia argentea* seeds was 4.27 ± 0.04% (dry weight basis). The oil content of *C. argentea* seeds was 7.82 ± 0.48% (dry weight basis). This oil yield is lower than that of conventional oilseeds such as cotton (13%), soybean (14%) and palm fruit (20%) [23]. Nevertheless, *C. argentea* seeds are lipid rich than that (3-5%) of maize seed oil, which is a known source of oil exploited in the world [6]. Therefore, *C. argentea* seeds could be exploited for oil production.

### 3.2 Physicochemical Properties of Seed Oil

The physicochemical parameters of *C. argentea* seed oil are shown in Table 1. The value of specific gravity was 0.92 ± 0.01 while the refractive index was about 1.47 ± 0.00. The specific gravity and refractive index of *C. argentea* oilseeds are within the range of those reported for most conventional edible oils [24, 25]. The specific extinction values at 232 and 270 nm were 1.7 ± 0.00 and 1.9 ± 0.00, respectively. These parameters are linked to the oxidative stability of *C. argentea* seed oil in terms of conjugated diene and triene products contents [26]. Lovibond colour in red light (Lr) of *C. argentea* seed oil was 20.2 ± 0.00. This parameter, generally related to carotenoids content and bleachability index of oil sample, is similar than that (20.4) of crude palm oil [8, 18]. Consequently, the studied seed oil could be used in cosmetic industries in view to the antioxidant activity and the protective skin effect of carotenoids [27]. The cloud point of *C. argentea* seed oil was -2.3 ± 0.00°C. This parameter which is the temperature of first stage of sample crystallization indicates the liquid state and the unsaturated level of this oil [18]. This unsaturated level of *C. argentea* seed oil is also linked to the semi-drying state indicated by the refractive index value [28]. With regard to this cloud point value (-2.3 ± 0.00°C), *C. argentea* seed oil is more unsaturated than palm olein (4°C), sesame seed oil (0°C) and mixture maize seed oil/palm olein (-1.9°C) [29, 30].

The effect of temperature on viscosity and the Arrhenius plot of *C. argentea* seed oil are depicted in Figure 1. The viscosity of liquids as vegetable oil is commonly perceived as thickness, or resistance to pouring [31]. The viscosity value (53.08 ± 0.28 mPas) at 20°C of *C. argentea* seed oil was in the range (50-100 mPas) of most vegetable oils [32]. This value decreases exponentially to 9.55 mPas when temperature increases from 20 to 80°C. The Arrhenius plot derived from the exponentially curve of viscosity indicate relatively low value (22.63 ± 0.01 kJ/mol) of activation energy. These results, linked to rheological properties of *C. argentea* seed oil, corroborate the fluid

state of this studied oil at ambient temperature and this physical characteristic could be suitable in food industries to provide texture and softness to products [33].

**Table 1.** Physicochemical properties of *C. argentea* seed oil.

| Parameters | Value |
|---|---|
| Specific gravity at 20°C | 0.92 ± 0.01 |
| Refractive index at 20°C | 1.47 ± 0.00 |
| Specific extinction at 232 nm | 1.7 ± 0.00 |
| Specific extinction at 270 nm | 1.9 ± 0.00 |
| Colour lovibond (Lr) | 20.2 ± 0.00 |
| Viscosity at 20°C (mPas) | 53.08 ± 0.28 |
| Activation energy (kJ/mol) | 22.63 ± 0.01 |
| Cloud point (°C) | - 2.3 ± 0.00 |
| pH at 25°C | 5.20 ± 0.02 |
| Acid value (mg KOH/g) | 4.68 ± 1.62 |
| Peroxide value (meq $O_2$/kg) | 10.33 ± 0.58 |
| Iodine value (g $I_2$/100 g) | 124.08 ± 1.22 |
| Saponification value (mg KOH/g) | 170.17 ± 1.62 |

All values are mean ± SD of three replicates

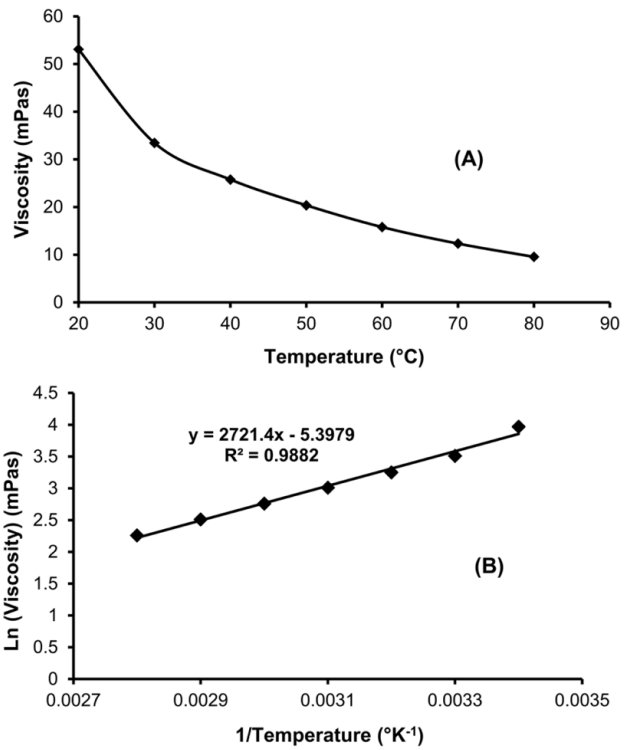


**Figure 1.** Effect of temperature on *C. argentea* seed oil viscosity (A) and Arrhenius plot (B) obtained. Experiments were performed by measuring viscosity of oil sample in the temperature range of 20 to 80°C.

The visible and near infrared spectrum of *C. argentea* seed oil is shown in Figure 2. In this spectrum, the wavelength range of visible domain was of 400 to 800 nm while that of near infrared domain was of 800 to 2500 nm. The visible domain of this spectrum showed two maximum absorbances of 1.65 and 0.85 at 450 and 660 nm, respectively. The near infrared domain of this spectrum showed four main maximum absorbances of 0.9, 0.8, 2.9 and 1.7 at 1200, 1400, 1725 and 2150 nm, respectively. The maximum absorbances observed at 450 and 660 nm are related to carotenoids and chlorophyll compounds of the seed oil, respectively [34]. As concern the maximum absorbances observed at 1200, 1400, 1725 and 2150 nm, they are related to C-H stretching 2nd overtone (oil), C-H stretching 1st overtone (oil), CO stretching 1st overtone (oil), and C-H bending 2nd overtone (oil), respectively [35]. Free fatty acids (FFA) of the studied seed oil are characterized by their carboxylic acid, C=O, absorption (CO stretching 1st overtone) at 1725 nm whereas iodine value (IV) is characterized by absorption (vibration of C-H *cis*-unsaturation bonds) at 2150 nm [36]. The maximum absorption band at 1940 nm which is related to the moisture (water) content was not observed in the NIR spectrum of *C. argentea* seed oil [37]. Compared to the NIR spectrum of rapeseed oil, *C. argentea* seed oil was showed more unsaturation due to the highest absorption at 2150 (iodine value) and more stability to deterioration due to the lowest absorption at 1940 nm (moisture content) [35].

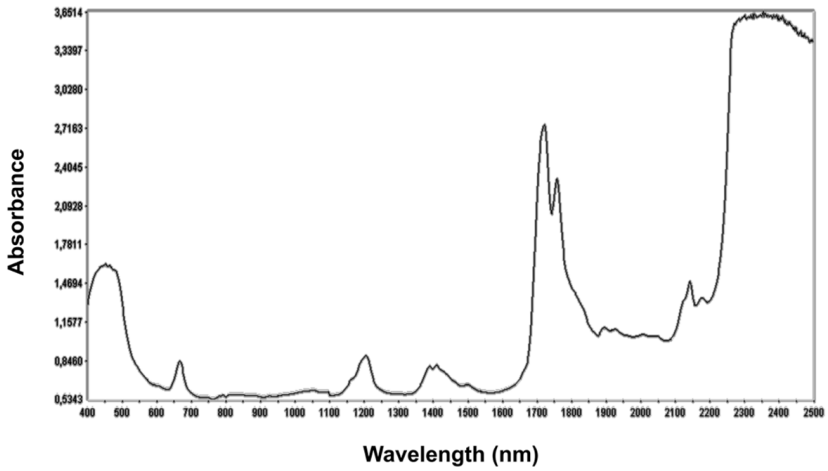


**Figure 2.** Visible and NIR spectrum of *C. argentea* seed oil. Experiments were performed by measuring absorbance of oil sample in the wavelengths range varying from 400 to 2500 nm.

The food value of a greasy substance depends on its free fatty acids (FFA) content measured by the acid value. The acid and peroxide values of *C. argentea* seed oil were 4.68 ± 1.62 mg KOH/g and 10.33 ± 0.58 meq $O_2$/kg, respectively. These values are higher than those (4 mg KOH/g and 10 meq $O_2$/kg) recommended by the Codex-Alimentarius [25] for edible oils. Nevertheless, *C. argentea* seed oil could not grow rancid easily with regard to the peroxide value less than 20 meq $O_2$/kg [38]. Iodine value (124.08 ± 1.22 g $I_2$/100 g) determined in this study is higher than those of other unsaturated oils such as groundnut (96 g $I_2$/100 g), cottonseed (112 g $I_2$/100 g) and rapeseed (122 g $I_2$/100 g)

oils [39]. In view of the results above, the studied oilseed consist predominately in polyunsatured fatty acids and could be nutritionally beneficial to patients suffering from most of lipid disorders [33]. In addition, *C. argentea* seed oil could be recommended for soap making and in the manufacture of lather shaving creams due to its high saponification value (170.17 ± 1.62 mg KOH/g) [40].

### 3.3 Biochemical and Nutritive Properties of Seed Oil

The biochemical and nutritive properties of *C. argentea* seed oil are shown in Table 2. Intrinsic biochemical parameters such as moisture, unsaponifiable matter, total fatty matter and total saponifiable matter were respectively closed to 0.23 ± 0.02%, 1.47 ± 0.21%, 99.75 ± 0.02% and 98.28 ± 0.21% (Table 2). The unsaponifiable matter content of this oilseed is higher than those reported for other high value oils such as cotton seed oil (0.52%), peanut oil (0.33%) and palm kernel oil (0.22%) [41]. Therefore *C. argentea* seed could be used as a good source of stabilizers in cosmetic and food industry [6]. In addition, *C. argentea* seed oil could have more technological ability with regard to its impurities content (0.016 ± 0.00%) which is lower than that (0.024%) of palm oil [18].

**Table 2.** Biochemical and nutritive properties of *C. argentea* seed oil.

| Parameters | Value |
|---|---|
| Moisture (%) | 0.23 ± 0.02 |
| Impurities (%) | 0.016 ± 0.00 |
| Unsaponifiable matter (%) | 1.47 ± 0.21 |
| Total fatty matter (%) | 99.75 ± 0.02 |
| Total saponifiable matter (%) | 98.28 ± 0.21 |
| Phosphorus (mg/g) | 0.10 ± 0.00 |
| Vitamin A (mg/g) | 0.52 ± 0.01 |
| Vitamin E (mg/g) | 0.12 ± 0.01 |
| Palmitic acid ($C_{16:0}$) (%) | 19.13 ± 0.01 |
| Stearic acid ($C_{18:0}$) (%) | 7.02 ± 0.01 |
| Oleic acid ($C_{18:1}$) (%) | 22.34 ± 0.01 |
| Linoleic acid ($C_{18:2}$) (%) | 49.94 ± 0.01 |
| a-Linolenic acid ($C_{18:3}$) (%) | 1.56 ± 0.01 |

All values are mean ± SD of three replicates

The chromatographic profiles of vitamin A and vitamin E in *C. argentea* seed oil are given in Figure 3 and Figure 4, respectively. Vitamin A and vitamin E contents of *C. argentea* seed oil were 0.52 ± 0.01 mg/g and 0.12 ± 0.01 mg/g, respectively (Table 2). In vegetable oils, vitamin A is provided by β-carotene which plays an important role in human health by acting as biological antioxidants protecting cells and tissues from the damaging effects of free radicals and singlet oxygen [42]. Vitamin A is an essential nutrient needed in small amounts by humans for the normal functioning of the visual system, growth and development, maintenance of epithelial cellular integrity, immune function, and reproduction [43]. The vitamin A content of *C. argentea* seed oil is lower than that reported (1 mg/g) for palm oil [24]. Nevertheless, the consumption

of this oilseed could cover vitamin A needs for infant (0 to 6 months), which are estimated at 0.375 mg per day [44]. Vitamin E content of *C. argentea* seed oil was compared favourably with those (0.12 and 0.14 mg/g) of soybean oil and groundnut oil which are used in food and cosmetic industries [45]. The main biological function of vitamin E is the protection of the polyunsaturated fatty acids of cell membranes from free-radical damage in the oxidative stress [46].

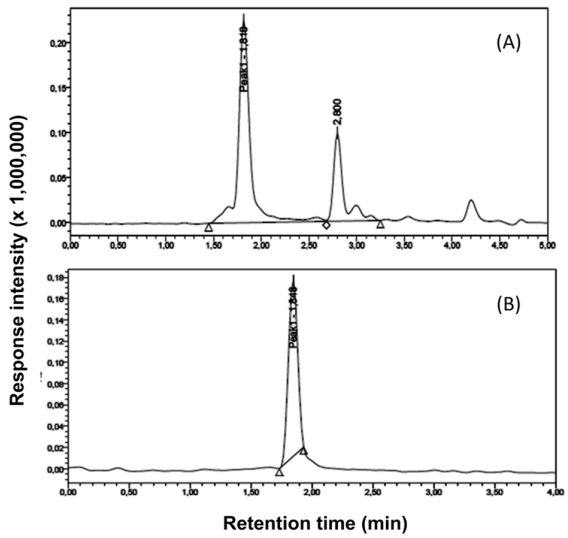


**Figure 3.** Chromatographic profile of *C. argentea* seed oil vitamin A. (A): oil sample; (B): Standard vitamin A (retinol palmitate). Experiments were performed in triplicate by high performance liquid chromatographic analysis (HPLC) of oil sample. Vitamin A detection was done at 325 nm.

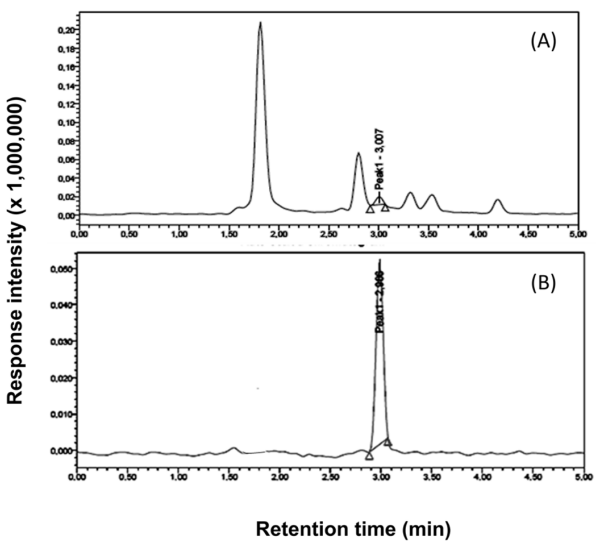


**Figure 4.** Chromatographic profile of *C. argentea* seed oil vitamin E. (A): oil sample; (B): Standard vitamin E (α-tocopherol acetate). Experiments were performed in triplicate by high performance liquid chromatographic analysis (HPLC) of oil sample. Vitamin E detection was done at 292 nm.

Chromatographic profiles of fatty acids composition and their relative amounts in *C. argentea* seed oil are given in Figure 5 and Table 2, respectively. Fatty acid proportions of the studied seed oil highlighted the presence of five compounds namely palmitic (19.13 ± 0.01%), stearic (7.02 ± 0.01%), oleic (22.34 ± 0.01%), linoleic (49.94 ± 0.01%) and a-linolenic (1.56 ± 0.01%) acids (Table 2). Polyunsaturated fatty acids (PUFA) of the studied oil were essentially made up of linoleic and a-linolenic acids while palmitic and stearic acids was the saturated fatty acids (SFA) detected. The proportions of PUFA and SFA were 51.5 and 26.15%, respectively. Total unsaturated fatty acids (UFA) represented 73.84% of total fatty acids. Polyunsaturated fatty acids (PUFA) amounts of *C. argentea* seed oil is higher than those reported for high value conventional seed oils such as canola (32%), cottonseed (50%) and peanut (33%) oils [38]. The higher content of total PUFA observed in the studied oil may confer flexibility, fluidity and selective permeability to cellular membranes and may also be beneficial for reducing cardiovascular disease risk [47]. The PUFA profile, essentially made up of linoleic and a-linolenic acids could explain the susceptibility of *C. argentea* seed oil to oxidative rancidity [52]. In view of the fatty acids profile and the linoleic acid content (49.94 ± 0.01%), *C. argentea* seed oil could be categorized as linoleic oil such as cottonseed (53.2%), soybean (52.1%), black cumin (48.3%), kenaf (45.9%) and sesame (45%) oils [33]. So, the consumption of this studied seed oil could be advantageous for decreasing LDL-cholesterol (bad-cholesterol) and improve the lipoprotein profile of the subjects [48]. Indeed, the positive effect of linoleic acid on LDL-cholesterol maybe due to the metabolites γ-linolenic and dihomo-γ-linolenic acids obtained by Δ6 desaturation [49]. However, an excess of linoleic acid promotes an inflammatory status in the human body and the n-6/n-3 ratio (4:1) requires this essential fatty acid consumption to be decreased [9]. Indeed, the highest value (32:1) of n-6/n-3 ratio may constitute an unfavorable factor for using *Celosia argentea* seed oil as food ingredient. The relatively higher linoleic acid content of *C. argentea* seed oil could also be useful in cosmetic industries to decrease trans-epidermal water loss and to eliminate scaly lesions common in patients with essential fatty acid deficiency [50]. Moreover, the highest a-linolenic acid content of *C. argentea* seed oil than that of most common conventional linoleic oils such as safflower (0.3%) and cotton (0.2%) seed oils is an advantageous property for anti-inflammatory, anti-thrombotic, anti-hypertensive and anti-arrhythmic actions in human nutrition [33]. Indeed, the a-linolenic acid content (1.58%) of *Celosia argentea* seed oil is higher than the minimum level (0.8%) recommended for health benefit in human nutrition [51]. Nevertheless, this amount of a-linolenic acid which is above 1% constitutes an unfavourable property for using this oil in food frying [23]. Therefore, *C. argentea* seed oil could be used in human nutrition for seasoning.

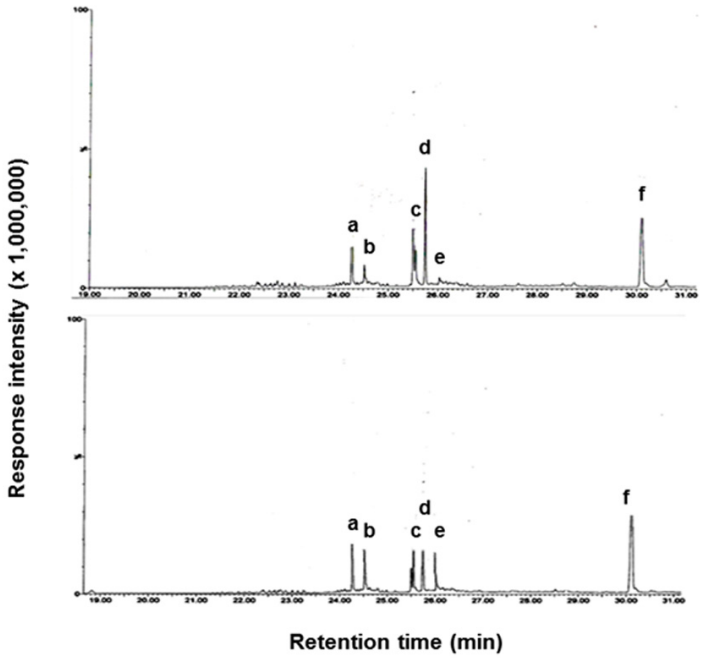


**Figure 5.** Gas chromatographic profile of *C. argentea* seed oil fatty acids. (A): oil sample; (B): fatty acids standards; (a): palmitic acid, (b): stearic acid; (c): oleic acid; (d): linoleic acid; (e): a-linolenic acid; (f): erucic acid (internal standard). Experiments were performed in triplicate by gas chromatographic analysis (GC-MS) of fatty acids methyl esters derived from *C. argentea* seed oil.

## 4. CONCLUSION

It could be concluded in view of the results of the present investigation that *C. argentea* seed oil may constitute an alternative source of bioactive compounds for food, cosmetic and pharmaceutical industries. Indeed, the physicochemical properties make the studied seed oil suitable in cosmetic industries for skin care products as soaps and lather shaving. As regards biochemical and nutritive properties, *C. argentea* seed oil is a suitable source of vitamin A and vitamin E. Furthermore, the relatively higher content of linoleic acid confers to this oil, good edible, cosmetic and dietetic values.

## REFERENCES

[1] Ramadan M.F., Sharanabasappa G., Seetharam Y.N., Seshagiri M. and Moersel J.T., Characterisation of fatty acids and bioactive compounds of kachnar (*Bauhinia purpurea* L.) seed oil, *Food Chem*., 2006; **98**: 359-365.

[2] Aluyor E., Ozigagu C., Oboh O. and Aluyor P., Chromatographic analysis of vegetable oils: A review, *Sci. Res. Essay*, 2009; **4**: 191-197.

[3] Kamal-Eldin A., Effect of fatty acids and tocopherols on the oxidative stability of vegetable oils, *Eur. J. Lipid Sci. Technol.,* 2006; **58**: 1051-1061.

[4] Elfalleh W., Ying M., Nasri N., Hua H.S., Guasmi F. and Ferchichi A., Fatty acids from Tunisian and Chinese pomegranate (*Punica granatum* L.) seeds, *Int. J. Food Sci. Nutr*., 2011; **62**: 200-206.

[5] FAO, *Fats and Fatty Acids in Human Nutrition*. FAO, Geneva, 2010.

[6] Gunstone F.D., Fatty Acid Structure; in Gunstone F.D., Harwood J.L. and Padley F.B., eds., *The Lipid Handbook*, 2nd Edn., Chapman and Hall, London, 1999; 1-19.

[7] Naudet M., Soulier J., Farines M., Principaux Constituants Chimiques des Corps Gras; in: Karleskind, ed., *Manuel des Corps Gras*, Paris, 1992; 65-115.

[8] Singh, Essential fatty acids, DHA and human brain, *Indian J. Pediatrics*, 2005; **72**: 239-242.

[9] Simopoulos A.P., Human requirement for n-3 polyunsaturated fatty acids, *Poultry Sci*., 2000; **79**: 961-970.

[10] Anhwange B.A., Ikyenge B.A., Nyiatagher D.T. and Ageh J.T., Chemical analysis of *Citrullus lanatus* (Thumb), *Cucumeropsis mannii* (Naud) and *Telfairia occidentalis* (Hook F.) seeds oils, *J. Appl. Sci. Res*., 2010; **6**: 265-268.

[11] Anwer T., Bhanger M.I., Anwar F., Khan M., Shahaid R. and Iqbal S., A comparative characterization of different non-conventional oilseeds found in Pakistan, *J. Chem. Soc. Pak*., 2006; **28**: 144-148.

[12] Badifu G., Food potentials of some non-conventional oilseeds grown in Nigeria, *Plant Food Hum. Nutr.*, 1993; **43**: 211-224.

[13] Leung W.T.W., Busson F. and Jardin C., *Food Composition Table for Use in Africa*, FAO, Roma, 1968.

[14] Patel B.A., Patel P.U. and Patel R.K., Physicochemical and phytochemical investigations of seeds of *Celosia argentea* Linn., *Int. J. Pharm. Appl. Sci*., 2010; **10**: 124-126.

[15] Ali M.A., Sayeed M.A., Reza M.S., Yeasmin S. and Khan A.M., Characteristics of seed oils and nutritional compositions of seeds from different varieties of *Momordica charantia* cultivated in Bangladesh, *Czech J. Food Sci*., 2008; **26**: 275-283.

[16] Ejikeme P.M., Obasi L.N. and Egbuonu A.C., Physicochemical and toxicological studies on *Afzelia africana* seed and oil, *Afr. J. Biotechnol*., 2010; **9**: 1959-1963.

[17] IUPAC, *Standard Methods for the Analysis of Oils, Fats and Derivatives*, 6th Edn., Pergamon, Oxford, 1979.

[18] MPOB, *A Compendium of Test on Palm Oil Products, Palm Kernel Products, Fatty Acids, Food Related Products and Other*, Kuala Lumpur, Malaysia, 2005.

[19] Afane E., Lando G., Biyiti L., Ossima G.A. and Atchou G., Boiling palm oil vapours, a broncho-annoying acid, *Med. Afr. Noire*, 1997; **44**: 604-607.

[20] AOAC, *Official Methods of Analysis*, 15th Edn., Association of Official Analytical Chemists, Washington DC, 1997.

[21] Gimeno E., Castellote A.I., Lamuela-Ravento R.M. and Lopez-Sabater M.C., Rapid determination of vitamin E in vegetable oils by reversed phase high-performance liquid chromatography, *J. Chromatography*, 2000; **881**: 251-254.

[22] European Communities, Determination of Free Fatty Acid Methyl Esters; in *Characteristics of Olive Oil and the Relevant Methods of Analysis*, Geneva, 1991.

[23] Nzikou J.M., Mvoula-Tsieri M., Matos L., Matouba E., Ngakegni-Limbili A.C., Linder M. and Desobry S., *Solanum nigrum* L. seeds as an alternative source of edible lipids and nutriment in Congo Brazzaville, *J. Appl. Sci*., 2007; **7**: 1107-1115.

[24] Nzikou J.M., Bouanga-Kalou G., Matos L., Ganongo-Po F.B., Mboungou-Mboussi P.S., Moutoula F.E., Panyoo-Akdowa E., Silou T.H. and Desobry S., Characteristics and nutritional evaluation of seed oil from Roselle (*Hibiscus sabdariffa L.*) in Congo-Brazzaville, *Curr. Res. J. Biol. Sci.*, 2011; **3**: 141-146.

[25] Codex-Alimentarius, *Fats and Vegetable Oils*, FAO ed, Geneva, 1993.

[26] Anwar F., Chata S.A.S. and Hussain A.I., Assessment of oxidative deterioration of soybean oil at ambient and sunlight storage, *Grasas Acietes*, 2007; **58**: 390-395.

[27] Platon J.F., Lipids in cosmetology, *OCL*, 1997; **4**: 275-281.

[28] Rossell J.B., Vegetable Oils and Fats; in Rossell J.B., ed., *Analysis of Oilseeds, Fats and Fatty Foods*, London, 1991: 261-325.

[29] Teah Y.K., Improvements in the Frying Quality of Vegetable Oils by Blending with Palm Olein; in MPOB ed., *Palm Oil Developments*, Malaysia, 1988; 1-4.

[30] Nor-Aini I. and Hanirah H., Resistance to Crystallisation of Single and Fractionated Palm Olein; in K.G. Berger ed., *Oils and Fats in Food Applications*, Bridgewater, 1997; 1-7.

[31] Ndangui C.B., Kimbonguila A., Nzikou J.M., Matos L., Pambou-Tobi N., Abena A., Silou T., Scher J. and Desobry S., Nutritive composition and properties physico-chemical of gumbo (*Abelmoschus esculentus* L.) seed oil, *Res. J. Env. Earth Sci.*, 2010; **2**: 49-54.

[32] Besbes S., Blecker C., Deroanne C., Lognay G., Drira N.E. and Attia H., Quality characteristics and oxidative stability of date seed oil, *Food Sci. Technol. Int.*, 2004; **10**: 333-338.

[33] Dubois V., Breton S., Linder M., Fanni J. and Parmentier M., Fatty acid profiles of 80 vegetable oils with regard to their nutritional potential, *Eur. J. Lipid Sci. Technol.*, 2007; **109**: 710-732.

[34] Psomiadou E. and Tsimidou M., Pigments in Greek virgin olive oils: Occurrence and levels, *J. Sci. Food Agric.*, 2001; **81**: 640-647.

[35] Kim K.S., Park S.H., Choung M.G. and Jang Y.S., Use of near-infrared spectroscopy for estimating fatty acid composition in intact seeds of rapeseed, *J. Crop Sci. Biotechnol.*, 2005; **10**: 15-20.

[36] Man Y.B. and Moh M.H., Determination of free fatty acids in palm oil by near-infrared reflectance spectroscopy, *J. Am. Oil Chem. Soc.*, 1998; **75**: 557-562.

[37] Curcio J.A. and Petty C.C., The near infrared absorption spectrum of liquid water, *J. Optical Soc. Am.*, 1951; **41**: 302–304.

[38] Matos L., Nzikou J.M., Matouba E., Pandzou-Yembe V.N., Mapepoulou T.G., Linder M. and Desobry S., Studies of *Irvingia gabonensis* seed kernels: Oil technological applications, *Pak. J. Nutr.*, 2009; **8**: 151-157.

[39] Kamal-Eldin A., Effect of fatty acids and tocopherols on the oxidative stability of vegetable oils, *Eur. J. Lipid Sci. Technol.*, 2006; **58**: 1051-1061.

[40] Eka O.U., Proximate composition of bush mango tree and some properties of dikafat, *Nigerian J. Nutr. Sci.*, 1980; **1**: 33-36.

[41] Kapseu C. and Parmentier M., Fatty acid composition of some vegetable oils from Cameroon, *Sci. Aliment*, 1997; **17**: 325-331.

[42] Zeb A. and Mehmood S., Carotenoids contents from various sources and their potential health applications, *Pak. J. Nutr.*, 2004; **3**: 199-204.

[43] Blomhoff R., Vitamin A metabolism: new perspectives on absorption, transport, and storage, *Physiol. Rev.*, 1991; **71**: 951-990.

[44] FAO, *Nutrition in Developing Countries*, FAO ed, Geneva, 2001.

[45] Dauqan E., Sani H.A., Abdullah A., Muhamad H. and Gapor M., Top vitamin E and beta carotene composition in four different vegetable oils, *Am. J. Appl. Sci.*, 2011; **8**: 407-412.

[46] Korchazhkina O., Jones E., Czauderna M., Spencer S.A. and Kowalczyk J., HPLC with UV detection for measurement of vitamin E in human milk, *Acta Chromatogr.*, 2006; **16**: 48-57.

[47] Das U.N., Essential fatty acids - a review, *Curr. Pharm. Biotechnol.*, 2006; **7**: 467-482.

[48] Mattson F.H. and Grundy S.M., Comparison of effects of dietary saturated, monounsaturated and polyunsaturated fatty acids on plasma lipids and lipoproteins in man, *J. Lipid Res.*, 1985; **26**: 194-202.

[49] Horrobin D.F. and Huang Y.S., The role of linoleic acid and its metabolites in the lowering of plasma cholesterol and the prevention of cardiovascular disease, *Int. J. Cardiol.*, 1987; **17**: 241-255.

[50] Aburjai T., Natsheh F.M., Plants used in cosmetics, *Phytother. Res.*, 2003; **17**: 987-1000.

[51] Delplanque B., Acides gras de la famille n3 : alphalinolénique (ALA) d'origine végétale et longues chaînes n3 (LCn3), *Oilseeds and Fats, Crops and Lipids*, 2004; **11**: 98-102.

[52] Yim H.S., Chye F.Y., Liow M.L., Ho C.W., Antioxidant potential of *Pleurotus porrigens* extract and application in sunflower oil during accelerated storage, *Chiang Mai J. Sci.*, 2013; **40**: 34-48.