Research Article

Characterization of Jamaican Delonix regia and Cassia fistula Seed Extracts

Andrea Goldson Barnaby, Raymond Reid, Vaughn Rattray, Ruth Williams, and Marcel Denny

Department of Chemistry, The University of the West Indies, Mona, Kingston 7, Jamaica

Correspondence should be addressed to Andrea Goldson Barnaby; andrea.goldson03@uwimona.edu.jm

Received 30 October 2015; Revised 1 February 2016; Accepted 14 February 2016

Academic Editor: Angel Catalá

Copyright © 2016 Andrea Goldson Barnaby et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Delonix regia and Cassia fistula seed extracts were evaluated for their antioxidant activity, total phenolics, ash, zinc and fatty acid content. Fourier Transform Infrared Spectroscopy (FTIR) was utilized to assess the chemical functionalities present within the seeds. Antioxidant activity was determined by the 2,2-diphenyl-1-picrylhydrazyl (DPPH) and Trolox equivalent antioxidant capacity (TEAC) assays. Total phenolics were determined by the Folin-Ciocalteu assay. Lipid extracts were characterized by nuclear magnetic resonance spectroscopy and gas chromatography/mass spectrometry. Zinc concentration was determined by atomic absorption spectroscopy. Extracts from the seeds of C. fistula had a higher antioxidant activity, free radical scavenging activity, and phenolic content than D. regia. FTIR revealed that the seeds are a rich source of protein with small quantities of fat. C. fistula extracts contained a higher percentage of total fat than D. regia. Palmitic acid was identified as the predominant saturated fatty acid in both extracts. Oleic acid and linoleic acid were identified in smaller quantities. Seed extracts may be considered for use in food and nutraceutical applications.

1. Introduction

Delonix regia and Cassia fistula can be found interspersed throughout the island of Jamaica and are primarily ornamental in nature. There is limited knowledge regarding the chemical composition of the seeds from trees grown in Jamaica. D. regia, Raffin (syn. Poinciana regia, Bojer ex Hook) also known as “flamboyant”, or “flame tree”, belongs to the Caesalpinioideae family (family: Leguminosae, subfamily: Fabaceae). The tree is known to reach heights of approximately 12 m, whereas the flowers, which cover the tree crown, show colours ranging from orange to red. Carotenoids (β-carotene, lutein, rubixanthin, β-cryptoxanthin, and zeaxanthin) and anthocyanins (peonidin-3-O-glucoside, petunidin-3-O-acetyl-glucoside, cyanidin-3-O-rutinoside, and cyanidin-3-O-glucoside) are responsible for the vibrant colours observed in the petals of the flower [1]. In Africa, extracts of the flower are used to produce a traditional health beverage which contains the phenolic acids 3,4,5-trihydroxybenzoic (gallic acid), 3,4-dihydroxybenzoic (protocatechuic acid), and 2-hydroxy 5-[(3,4,5 trihydroxyphenyl) carbonyl oxy] benzoic acid [2]. D. regia flower extract is known to also contain flavonols such as quercetin and its glycosides (quercetin-3-O-glucoside, quercetin-3-O-galactoside, rutin, quercetin-3-O-robioside, and quercetin trihexoside), as well as kaempferol rhamnosylhexoside and isorhamnetin rhamnosylhexoside [2]. Cassia fistula L. (family: Leguminosae, subfamily: Fabaceae) is a semi-wild Indian Laburnum that is widely cultivated in Mauritius but can also be found in Asia, Africa, Latin America, and the Caribbean. The tree has yellow flowers and is sometimes referred to as Golden Shower. C. fistula has been identified as a potentially novel source of free radical scavenging compounds [3]. Also in this case there is limited information on the chemical composition of extracts from the seeds of trees grown in Jamaica. In order to expand our knowledge on the chemical composition of seeds from these leguminous trees, chromatographic and spectroscopic techniques, as well as colorimetric methods, were applied. The antioxidant activity, total phenolics, fatty acid profile, and
zinc composition of the seed extracts were evaluated. Seeds were also analyzed utilizing FTIR.

2. Materials and Methods

2.1. Plant Material. D. regia and C. fistula seed pods were randomly collected from trees located on the campus of the University of the West Indies, Kingston, Jamaica. Seeds were removed from mature dry pods. Ten pods represented one sample subset. Whole seeds were ground using a laboratory mill (30 sec at 25°C, Ika-Werke M20 Analytical Mill, Staufen, Germany).

2.2. The 1,1-Diphenyl-2-picrylhydrazyl (DPPH) Radical Scavenging Assay. The DPPH assay was performed according to the method of Brand-Williams et al. [4]. Samples (200 mg) were extracted with methanol (2 mL, 80%) containing hydrochloric acid (1%) at room temperature on an orbital shaker (200 rpm, Gallenkamp, England). Extracts were centrifuged (3200 rpm, 10 min) and the resulting supernatant was diluted with methanol (1:3, 1mL) and reacted with DPPH (0.004%, 1mL, 30 min). The absorbance was measured at 517 nm using a spectrophotometer (Helios Omega, Thermo Fisher Scientific). A standard calibration curve was generated and the results were expressed as mg/g gallic acid equivalents. Samples were analyzed in triplicate. Data obtained were useful to calculate the radical scavenging capacity according to the following formula:

\[ \% = \left[ 1 - \frac{A_1}{A_0} \right] \times 100, \]  

where \( A_1 \) is absorbance of sample at 517 nm and \( A_0 \) is absorbance of control at 517 nm.

2.3. Total Phenolic Content. Total phenolics were determined using the Folin- Ciocalteu assay with modifications [5]. Samples (200 mg) were extracted with methanol (2 mL, 80%) containing hydrochloric acid (1%) at room temperature on an orbital shaker (200 rpm, Gallenkamp, England). Extracts were centrifuged (3200 rpm, 10 min) and the resulting supernatant (100 \( \mu \)L) reacted with Folin-Ciocalteu reagent (10%, 750 \( \mu \)L) and mixed for 5 min followed by addition of \( \text{Na}_2\text{HCO}_3 \) solution (7.5%, 750 \( \mu \)L). The solution was incubated at 22°C (1.5 h) and the absorbance was measured at 760 nm using a spectrophotometer (Helios Omega, Thermo Fisher Scientific). A standard calibration curve of gallic acid (0–200 mg/L) was generated and the results were expressed as mg/g gallic acid/g.

2.4. Trolox Equivalent Antioxidant Capacity (TEAC) Assay. Free radical scavenging activity of methanolic extracts was also determined as Trolox equivalence [6]. 2,2’-Azinobis-(3-ethylbenzothiazoline-6-sulfonic acid) radical (ABTS+, 5 mM) was prepared in sodium phosphate buffer (7 mM, pH 7). Samples (20 \( \mu \)L) were combined with ABTS•− (2 mL) and the absorbance readings were recorded after 2 min at 750 nm. A standard calibration curve of Trolox (0–300 \( \mu \)M) was prepared.

2.5. Lipid Extraction. Oil was Soxhlet extracted from the dried, milled seeds with petroleum ether (bp 80–100°C, reflux), and concentrated in vacuo. Percent crude fat (dry weight basis) was determined gravimetrically.

2.6. Methylation of Lipid Extracts. Soxhlet extracted oil samples (50 \( \mu \)L) were trimethylated with methanol/acetyl chloride solution [7]. The resulting fatty acid methyl esters (FAMEs) were determined by gas chromatography-mass spectrometry (GC-MS).

2.7. Gas Chromatography-Mass Spectrometry. Methylated oil in hexane (1.0 \( \mu \)L) was chromatographed on an HP6890 series Gas Chromatograph interfaced with an HP5973 Mass Selective Detector. Constituent FAMEs were eluted with helium carrier gas (flow rate 1 cm\(^3\)/min) through a DBMVX column (20 m × 0.18 mm i.d. × 1.0 \( \mu \)m film thickness, Agilent, Santa Clara, CA) in an oven programmed at 60°C for 3 min and increased at a ramp rate of 10°C/min up to 250°C for 15 min. Samples were injected at 230°C while the detector was maintained at 250°C. Constituents were identified by matching the mass spectra, National Institute of Standards and Technology (NIST) library of mass spectra (match quality > 80%).

2.8. \(^1\)H NMR and \(^{13}\)C NMR Spectroscopy. \(^1\)H NMR and \(^{13}\)C NMR characterization were performed on a Bruker BioSpin 500 MHz Spectrometer (Massachusetts, USA) at 500 MHz. A 5 mm probe was used for \(^1\)H NMR and \(^{13}\)C NMR experiments. Lipid extracts were run in deuterated chloroform (CDCl\(_3\)) at 25°C, with tetramethylsilane as the internal standard while for phenolic extracts, deuterated acetone was utilized as solvent.

2.9. Iodine Value. Iodine values were calculated based on the FAME content and were calculated utilizing the formula:

\[ \text{Predicted IV} = xC1 + yC2 + zC3. \]  

C1, C2, and C3 correspond to the relative percentage concentrations of unsaturated fatty acids (one, two, and three double bonds, resp.) whereas \( x, y, \) and \( z \) are coefficients \((x = 1, y = 1.5, \) and \( z = 2.62)\) [8].

2.10. Atomic Absorption Spectroscopy. Samples (1.5 g) were ashed in a muffle furnace (600°C for 1.5 h) and the resulting ash dissolved in HCl (10 mL, AR), diluted with deionized water, and filtered. Measurements for zinc were made using a Perkin Elmer 2380 Flame Atomic Absorption Spectrophotometer system equipped with the corresponding hollow cathode lamp at the time of analysis. The following parameters were utilized: lamp current 10 mA, wavelength 214 nm, and slit width 0.7 nm, with flame type consisting of air/acetylene and stoichiometric fuel flow at 0.9 to 1.21 min\(^{-1}\). Stock solutions of zinc were made and standard calibration curves were prepared. Results are expressed as ppm.
3. Fourier Transform Infrared Spectroscopy

A Bruker Vector 22 Fourier Transform Infrared (FTIR) Spectrometer was utilized to record the infrared spectra of milled seed samples of D. regia and C. fistula. OPUS software was used to acquire and manipulate the spectral data.

3.1. Data Analyses. Samples were analyzed in triplicate. Means and standard deviations of the data were presented.

4. Results and Discussion

Interest in the chemical and physiological properties of extracts from D. regia and C. fistula continues to increase with recent papers documenting their potential health benefit and applicability. Galactomannan, a storage polysaccharide, was isolated from the seeds of D. regia [9] with potential use as a thickening and stabilizing agent in the food industry [10]. Sesquiterpene (E) nerolidol (38.0%) was detected as the major essential oil in flowers of the tree and phytol (16.1%) in the leaves of C. fistula [11]. The ethyl acetate extract from the flowers of C. fistula has shown antifeedant and larvicidal effects on insects. Rhein (1,8-dihydroxy-anthraquinone-2-carboxylic acid) was identified as the active component from the ethyl acetate extract [12].

5. Free Radical Scavenging Activity and Total Phenolics

Legumes are a source of natural antioxidants [13]. Their antioxidant activity is based on the presence of different classes of compounds which includes phenolic acids and their derivatives. Derivatives include, for example, flavanols, anthocyanins, tocopherols, and vitamin C [13]. In a study conducted by Amarowicz and Raab, it was found that lentil (Lens culinaris) and faba beans (Vicia faba minor) possessed high levels of antioxidant activity [14]. The dominant phenolics identified in extracts of red lentil were quercetin diglycoside, catechin, digallate procyanidin, and p-hydroxybenzoic acid [15].

Extracts from C. fistula have been used extensively in traditional Indian medicine. High levels of antioxidants and phenolics (proanthocyanidins and flavonoids) have been detected in the pods [16] with bark extracts being reported as possessing antidiabetic properties [17]. Leaf, flower, and bark extracts of D. regia also possess antioxidant and antimicrobial attributes [18]. D. regia leaf extracts exhibit anti-inflammatory activity [19]. Whereas the phenolic composition of the flowers of D. regia has been previously reported [2], there is limited information regarding the phenolic content of the seeds.

The antioxidant activity of D. regia and C. fistula seed extracts was determined by the DPPH free radical scavenging and TEAC assays and total phenolics by the Folin-Ciocalteu assay. The DPPH assay is frequently utilized in assessing the antioxidant properties of extracts [20]. The DPPH free radical is stable and changes colour from violet to yellow upon the addition of a proton. This decrease in colour may be quantified spectrophotometrically.

6. Crude Lipid Extract, Fatty Acid Profile, and Iodine Value

C. fistula seed extracts contained higher levels of total lipids (8.22 ± 0.47%) compared to D. regia (1.41 ± 0.65%). Palmitic acid was identified as the predominant fatty acid in both seed extracts (Table 2). Prior studies on D. regia and C. fistula seeds grown in Rajasthan and Nigeria identified linoleic acid as the predominant fatty acid present [23–26]. Linoleic acid was only identified in small quantities. C. fistula extracts contained more minor fatty acids compared to D. regia (Table 3). The predicted iodine values of D. regia and C. fistula were 44 and 16, respectively. Lipid extracts from C. fistula are therefore expected to be more stable to oxidation than D. regia. β sitosterol (3.99 ± 1.08%) and benzyl alcohol (3.27 ± 0.48%) were also identified in seed extracts from C. fistula. Increased oil yields may be obtained by the utilization of a pressure based system for extraction. The oil extract of cowpeas (Vigna unguiculata) has been shown to possess antidiabetic properties [27]. Oil extracts from C. fistula and D. regia may be evaluated for potential medicinal activity.

7. 1H and 13C NMR Spectroscopic Data

Higher levels of free radical scavenging activity and total phenolics were detected in the seed extracts of C. fistula compared to D. regia (Table 1). The free radical scavenging activity of C. fistula was twice that observed in D. regia. For the TEAC assay, values of 0.93 ± 0.02 and 1.71 ± 0.08 mg Trolox/g were obtained for D. regia and C. fistula seed extracts, respectively, thereby further substantiating that seed extracts of C. fistula have higher levels of antioxidant activity when compared to D. regia.

Table 1: Antioxidant activity and total phenolic content of D. regia and C. fistula extracts expressed as gallic acid equivalents (GAE).

| Parameters investigated | D. regia | C. fistula |
|-------------------------|----------|-----------|
| Antioxidant activity (mg/g) | 0.52 ± 0.02 | 1.15 ± 0.07 |
| Total phenolics (mg/g) | 1.54 ± 0.16 | 2.10 ± 0.26 |
| Free radical scavenging activity (%) | 15.30 ± 0.70 | 38.27 ± 1.25 |

Higher levels of free radical scavenging activity and total phenolics were detected in the seed extracts of C. fistula compared to D. regia (Table 1). The free radical scavenging activity of C. fistula was twice that observed in D. regia. For the TEAC assay, values of 0.93 ± 0.02 and 1.71 ± 0.08 mg Trolox/g were obtained for D. regia and C. fistula seed extracts, respectively, thereby further substantiating that seed extracts of C. fistula have higher levels of antioxidant activity when compared to D. regia.

Tannins have been reported as being the main contributors to the free radical scavenging properties of legume extracts [15]. Phenolic compounds contribute to antioxidant activity by serving as potent hydrogen donors due to the hydroxyl functionality present. They are able to scavenge free radicals, chelate metals which serve as catalysts in the production of free radicals, activate antioxidant enzymes, and inhibit oxidases [21]. Antioxidants assist in protecting the body from oxidative damage which may be caused by reactive oxygen species and results in several diseases, for example, cancer and cardiovascular disease [22]. Seed extracts of C. fistula and D. regia may prove to be a valuable source of natural antioxidants and may be considered for use in nutraceutical applications.

Higher levels of free radical scavenging activity and total phenolics were detected in the seed extracts of C. fistula compared to D. regia (Table 1). The free radical scavenging activity of C. fistula was twice that observed in D. regia. For the TEAC assay, values of 0.93 ± 0.02 and 1.71 ± 0.08 mg Trolox/g were obtained for D. regia and C. fistula seed extracts, respectively, thereby further substantiating that seed extracts of C. fistula have higher levels of antioxidant activity when compared to D. regia.

Lower levels of free radical scavenging activity and total phenolics were detected in the seed extracts of C. fistula compared to D. regia (Table 1). The free radical scavenging activity of C. fistula was twice that observed in D. regia. For the TEAC assay, values of 0.93 ± 0.02 and 1.71 ± 0.08 mg Trolox/g were obtained for D. regia and C. fistula seed extracts, respectively, thereby further substantiating that seed extracts of C. fistula have higher levels of antioxidant activity when compared to D. regia.

Tannins have been reported as being the main contributors to the free radical scavenging properties of legume extracts [15]. Phenolic compounds contribute to antioxidant activity by serving as potent hydrogen donors due to the hydroxyl functionality present. They are able to scavenge free radicals, chelate metals which serve as catalysts in the production of free radicals, activate antioxidant enzymes, and inhibit oxidases [21]. Antioxidants assist in protecting the body from oxidative damage which may be caused by reactive oxygen species and results in several diseases, for example, cancer and cardiovascular disease [22]. Seed extracts of C. fistula and D. regia may prove to be a valuable source of natural antioxidants and may be considered for use in nutraceutical applications.

Higher levels of free radical scavenging activity and total phenolics were detected in the seed extracts of C. fistula compared to D. regia (Table 1). The free radical scavenging activity of C. fistula was twice that observed in D. regia. For the TEAC assay, values of 0.93 ± 0.02 and 1.71 ± 0.08 mg Trolox/g were obtained for D. regia and C. fistula seed extracts, respectively, thereby further substantiating that seed extracts of C. fistula have higher levels of antioxidant activity when compared to D. regia.

Tannins have been reported as being the main contributors to the free radical scavenging properties of legume extracts [15]. Phenolic compounds contribute to antioxidant activity by serving as potent hydrogen donors due to the hydroxyl functionality present. They are able to scavenge free radicals, chelate metals which serve as catalysts in the production of free radicals, activate antioxidant enzymes, and inhibit oxidases [21]. Antioxidants assist in protecting the body from oxidative damage which may be caused by reactive oxygen species and results in several diseases, for example, cancer and cardiovascular disease [22]. Seed extracts of C. fistula and D. regia may prove to be a valuable source of natural antioxidants and may be considered for use in nutraceutical applications.
Table 2: Fatty acid profile of *D. regia* and *C. fistula* seed extracts.

| Fatty acid                | *D. regia* % | *C. fistula* % |
|---------------------------|--------------|----------------|
| Palmitic acid C16:0       | 41.59 ± 3.20 | 34.44 ± 6.39  |
| Stearic acid C18:0        | 24.10 ± 5.11 | 10.00 ± 0.93  |
| Oleic acid (omega 9) C18:1| 24.75 ± 3.75 | 6.46 ± 0.54   |
| Linoleic acid (omega 6) C18:2| 12.82 ± 2.11 | 6.29 ± 0.32   |

Table 3: Minor fatty acids identified in *C. fistula*.

| Fatty acid        | Percent composition |
|-------------------|---------------------|
| Pentadecylic acid C15:0 | 0.38 ± 0.03        |
| Palmitoleic acid C16:1  | 0.31 ± 0.08        |
| Margaric acid C17:0    | 0.62 ± 0.10        |
| Arachidic acid C20:0   | 4.65 ± 0.18        |
| Heneicosylic acid C21:0 | 0.83 ± 0.09       |
| Behenic acid C22:0     | 5.75 ± 0.83        |
| Lignoceric acid C24:0  | 4.20 ± 0.07        |
| Pentacosylic acid C25:0| 1.04 ± 0.01        |
| Cerotic acid C26:0     | 1.19 ± 0.12        |

8. Fourier Transform Infrared Spectroscopy

FTIR is a rapid method of analysis which is also increasingly being utilized to detect adulteration in samples [32–35]. The FTIR spectroscopy profile for *C. fistula* and *D. regia* was similar (Table 6, Figure 3). The major bands observed are due to the high protein content of the seeds. Bands...
observed at 3270.37 cm\(^{-1}\) (\textit{D. regia}) and 3285.75 cm\(^{-1}\) (\textit{C. fistula}) are indicative of N-H stretching vibrations present in the amide functionality of proteins. Amide N-H bending vibrations were observed at 1542.60 cm\(^{-1}\) (\textit{D. regia}) and 1539.80 cm\(^{-1}\) (\textit{C. fistula}). For secondary amides, the N-H bending vibrations were observed at 1238.54 cm\(^{-1}\) and 1243.64 cm\(^{-1}\) [36]. Bands at 1399.98 cm\(^{-1}\), 1402.21 cm\(^{-1}\), 1645.96 cm\(^{-1}\), and 1644.30 cm\(^{-1}\) were due to the carbonyl functionality of the amides. The appearance of these strong bands indicates the presence of protein in the solid state [36]. Bands observed at 1455.10 cm\(^{-1}\) (\textit{C. fistula}) and 1456.76 cm\(^{-1}\) (\textit{D. regia}) were due to bending deformation of C-H vibration with stretching vibrations being observed at 2852.90 cm\(^{-1}\), 2922.57 cm\(^{-1}\), 2857.90 cm\(^{-1}\), and 2926.49 cm\(^{-1}\). Other pronounced bands were observed at 1742.63 cm\(^{-1}\) (\textit{D. regia}) and 1745.18 cm\(^{-1}\) (\textit{C. fistula}) due to the carbonyl stretching vibrations of triacylglycerols present [36]. FTIR spectroscopy of methanolic extracts of the seeds revealed a broad band at

### Table 4: \(^1\text{H}\) Nuclear magnetic resonance spectroscopy data of seed lipid extracts.

| Proton | Functionality | \textit{D. regia} \(\delta\) (ppm) | \textit{C. fistula} \(\delta\) (ppm) |
|--------|--------------|---------------------------------|---------------------------------|
| \(\text{CH}_3\) | Terminal methyl | 0.86 | 0.81 |
| \(\text{CH}_2\) | Methylene | 1.28 | 1.23 |
| \(\text{CH}_2\text{-COO}\) | All acyl chains | 1.59 | 1.55 |
| \(\text{CH}_2\text{-CH}=\text{CH}\) | All unsaturated fatty acids | 2.01 | 1.98 |
| \(\text{C}==\text{C}-\text{CH}_2\text{-COO}\) | Protons attached to bis allylic carbon | 2.73 | 2.70 |
| \(\text{CH}_2\text{O}(\alpha)\) | Glycerol (triglycerides) | 4.15 | 4.08 |
| \(\text{CH}_2\text{O}(\beta)\) | Glycerol (triglycerides) | 5.26 | 5.20 |
| \(\text{CH}==\text{CH}\) | Olefinic protons | 5.34 | 5.28 |

### Table 5: \(^{13}\text{C}\) Nuclear magnetic resonance spectroscopy data of seed lipid extracts.

| Carbon | Assignment | \textit{D. regia} \(\delta\) (ppm) | \textit{C. fistula} \(\delta\) (ppm) |
|--------|------------|---------------------------------|---------------------------------|
| \(\alpha\)-\text{CH}_3 | Acyl chains | 13.88 | 13.85 |
| \(\beta\)-\text{CH}_3 | Acyl chains | 22.54 | 22.70 |
| C3 | Acyl chains | 24.78 | 24.72, 24.88 |
| C11 | Diallylic | 25.58 | 25.64 |
| C8–11 (oleyl) | Alillic | 27.12 | 26.62 |
| C8–14 (linoleyl) | Alillic | 27.12 | 27.21, 27.42, 27.75 |
| \(\text{CH}_2\text{n}\) | Acyl chains | 29.01–29.56 | 29.06–29.71 |
| C16 | Linoleyl | 31.42 | 31.53, 31.79, 31.93 |
| \(\alpha\)-C2 | Acyl chains | 33.83 | 33.84 |
| \(\beta\)-C2 | Acyl chains | 33.97 | 34.06, 34.20, 37.31 |
| \(\alpha\)-\text{CH}_2\text{O} | Glycerol moiety | 62.06 | 62.11 |
| \(\alpha\)-\text{CH}_2\text{O} | Glycerol moiety | 64.98 | 65.06 |
| \(\beta\)-\text{CH}_2\text{O} | Glycerol moiety | 69.01 | 68.89 |
| C12 | Linoleyl | 127.87 | 127.90 |
| C13 | Linoleyl | 128.05 | 128.08 |
| C9 | Oleyl | 129.61 | 129.72 |
| C10 | Oleyl | 129.91 | 130.02 |
| C10 | Linoleyl | 130.11 | 130.23, 132.76 |
| \(\alpha\)-C1 | Glycerol moiety | 172.65 | 172.88 |
| \(\beta\)-C1 | Glycerol moiety | 173.09 | 173.33 |
| C1 | Free fatty acid | 178.20 | 178.45 |
| C1 | Free fatty acid | 178.36 |
Table 6: FTIR spectroscopic data of seed samples of *D. regia* and *C. fistula*.

| Functionality                                    | *D. regia* cm\(^{-1}\) | *C. fistula* cm\(^{-1}\) |
|--------------------------------------------------|-------------------------|---------------------------|
| C-O-C (ether functionality, starch)              | 995.69                  | 1032.92, 1047.46          |
| N-H bending (secondary amide)                    | 1238.54                 | 1243.64                   |
| C=O bending vibration (primary amide)             | 1399.98                 | 1402.21                   |
| C-H vibration (bending deformation)              | 1456.76                 | 1455.10                   |
| N-H bending (amide II)                           | 1542.60                 | 1539.80                   |
| C=O (amide I)                                    | 1645.96                 | 1644.30                   |
| C=O stretching vibrations (lipids)                | 1742.63                 | 1745.18                   |
| CH stretching vibrations (Symmetric & asymmetric) | 2852.90, 2922.57         | 2857.90, 2926.49          |
| N-H stretching vibration (amide) & OH stretching vibrations (starch) | 3270.37 | 3285.75 |

Table 7: FTIR spectroscopic data of methanolic extracts of seed samples of *D. regia* and *C. fistula*.

| Functionality                                    | *D. regia* cm\(^{-1}\) | *C. fistula* cm\(^{-1}\) |
|--------------------------------------------------|-------------------------|---------------------------|
| C-O stretch                                      | 1049.09                 | 1052.94                   |
| C-C stretch (aromatic ring)                      | 1421.28                 | 1465.63                   |
| C-C stretch (aromatic ring)                      | 1619.91                 | 1633.41                   |
| C=O stretching vibrations                         | 1720.19                 | 1747.19                   |
| C-H stretch (aromatic ring)                      | 2908.13                 | 2908.13                   |
| C-H stretch (aromatic ring)                      | 2927.41                 | 2927.41                   |
| O-H stretch (phenolics)                           | 3384.45                 | 3363.25                   |

3384.45 cm\(^{-1}\) (*D. regia*) and 3363.25 cm\(^{-1}\) (*C. fistula*) which is due to the hydroxyl functionality of the phenolics present (Figure 4). The C-H stretch and C-C stretch due to the aromaticity of phenolics were also observed (Table 7). Bands at 1747.19 cm\(^{-1}\) (*C. fistula*) and 1720.19 cm\(^{-1}\) are indicative of the presence of a carbonyl substituent on the phenolic ring. Sharp bands at 1052.94 cm\(^{-1}\) (*C. fistula*) and 1049.09 cm\(^{-1}\) (*D. regia*) also indicate that the phenolics present may be further substituted producing the carbon-oxygen stretching vibration (Table 7).

9. Zn Composition

Seed extracts were found to contain 3.83 ± 0.60% (*D. regia*) and 5.48 ± 0.05% (*C. fistula*) ash. Zinc is an essential trace element which has antioxidant [37] and anti-inflammatory properties [38]. The ability of zinc to retard oxidative processes has been recognized for several years [39]. Seed samples were therefore analyzed for their zinc composition. *C. fistula* and *D. regia* seed extracts were found to contain similar concentrations of zinc, 34.5 ± 0.3 ppm and 38.4 ± 1.0 ppm, respectively.

10. Conclusion

The composition of *D. regia* and *C. fistula* seeds was investigated in the form of powder, ash, oil, phenolics, and antioxidant activity. The results indicate that the seeds are a rich source of proteins with fats and starch being present in small quantities. The seeds are also a source of antioxidants. This study further substantiates that extracts from the seeds of these trees may be of commercial value and warrant further investigation.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

[1] J. M. Veigas, P. Divya, and B. Neelwarne, “Identification of previously unreported pigments among carotenoids and anthocyanins in floral petals of Delonix regia (Hook.) Raf,” Food Research International, vol. 47, no. 1, pp. 116–123, 2012.
[2] F. A. Adjé, Y. F. Lozano, C. Le Gernvé et al., “Phenolic acid and flavonol water extracts of Delonix regia red flowers,” Industrial Crops and Products, vol. 37, no. 1, pp. 303–310, 2012.
[3] N. R. Bhalodia, R. N. Acharya, and V. J. Shukla, “Evaluation of in vitro antioxidant activity of hydroalcoholic seed extracts of Cassia fistula Linn,” Free Radicals and Antioxidants, vol. 1, no. 1, pp. 68–76, 2012.
[4] W. Brand-Williams, M. E. Cuvelier, and C. Beres, "Use of a free radical method to evaluate antioxidant activity," LWT—Food Science and Technology, vol. 28, no. 1, pp. 25–30, 1995.

[5] V. L. Singleton and J. A. Rossi Jr, "Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents," American Journal of Enology and Viticulture, vol. 16, pp. 144–158, 1965.

[6] N. P. Seeram, M. Aviram, Y. Zhang et al., "Comparison of antioxidant potency of commonly consumed polyphenol-rich beverages in the United States," Journal of Agricultural and Food Chemistry, vol. 56, no. 4, pp. 1415–1422, 2008.

[7] A. Masood, K. D. Stark, and N. Salem Jr., "A simplified and efficient method for the analysis of fatty acid methyl esters suitable for large clinical studies," Journal of Lipid Research, vol. 46, no. 10, pp. 2299–2305, 2005.

[8] N. B. Kyriakidis and T. Katsilolis, "Calculation of iodine value from measurements of fatty acid methyl esters of some oils: comparison with the relevant American Oil Chemists’ Society method," Journal of the American Oil Chemists’ Society, vol. 77, no. 12, pp. 1235–1238, 2000.

[9] Y. Tamaki, T. Teruya, and M. Tako, "The chemical structure of galactomannan isolated from seeds of Delonix regia," Bioscience, Biotechnology and Biochemistry, vol. 74, no. 5, pp. 1110–1112, 2010.

[10] J. Pacheco-Aguirre, G. Rosado-Rubio, D. Betancur-Ancona, and L. Chel-Guerrero, "Physicochemical properties of carboxymethylated flamboyant (Delonix regia) seed gum," CyTA—Journal of Food, vol. 8, no. 3, pp. 169–176, 2010.

[11] O. Tzakou, A. Loukis, and A. Said, "Essential oil from the flowers of Cassia fistula L.," Journal of Essential Oil Research, vol. 19, no. 4, pp. 360–361, 2007.

[12] V. D. Shewale, T. A. Deshmukh, L. S.Patil, and V. R. Patil, "Anti-inflammatory activity of Delonix regia (Boj. Ex. Hook.)," Advances in Pharmacological Sciences, vol. 2012, Article ID 789713, 4 pages, 2012.

[13] K. Zhou and L. Yu, "Effects of extraction solvent on wheat bran antioxidant activity estimation," LWT—Food Science and Technology, vol. 37, no. 7, pp. 717–721, 2004.

[14] A. P. Kulkarni, S. M. Aradhya, and S. Divakar, "Isolation and identification of a radical scavenging antioxidant—punicalagin from pith and carpellary membrane of pomegranate fruit," Food Chemistry, vol. 87, no. 4, pp. 551–557, 2004.

[15] M. Gerber, M.-C. Boutron-Ruault, S. Hercberg, E. Riboli, A. Scalbert, and M.-H. Siess, "Food and cancer: state of the art about the protective effect of fruits and vegetables," Bulletin du Cancer, vol. 89, no. 3, pp. 293–312, 2002.

[16] A. Arora, R. Sen, and J. Singh, "Fatty acid composition of Delonix regia (Gulmohar) seed oil from arid zone of Rajasthan," Journal of the Indian Council of Chemists, vol. 27, no. 2, pp. 150–152, 2010.

[17] A. Arora and R. Sen, "Determination of fatty acids in plant seeds of leguminosae family from arid zone of Rajasthan," Asian Journal of Chemistry, vol. 22, no. 3, pp. 2474–2476, 2010.

[18] A. Adewuya, R. A. Onderine, B. V. S. K. Rao, R. B. N. Prasad, and B. Anjaneyulu, "Chemical component and fatty acid distribution of Delonix regia and Peltophorium pterocarpum seed oils," Food Science and Technology Research, vol. 16, no. 6, pp. 565–570, 2010.

[19] A. Adewuya and R. A. Onderine, "Analysis of the mineral nutrient, chemical composition and distribution of fatty acids in the lipid classes of the seed oils of underutilized legumes from Nigeria," Rivista Italiana delle Sostanze Grasse, vol. 88, no. 2, pp. 89–96, 2011.

[20] M. Ashraduzzaman, M. A. Alam, S. Khatun, S. Banu, and N. Absar, "Vigna unguiiculata linn. Walp. Seed oil exhibiting anti-diabetic effects in alloxan induced diabetic rats," Malaysian Journal of Pharmaceutical Sciences, vol. 9, no. 1, pp. 13–23, 2011.

[21] V. Thoss, P. J. Murphy, R. Marriott, and T. Wilson, "Triacylglycerol composition of British bluebell (Hyacinthoides non-scripta) seed oil," RSC Advances, vol. 2, no. 12, pp. 5314–5322, 2012.

[22] W. Kamm, F. Dionisi, C. Hischenhuber, and K.-H. Engel, "Authenticity assessment of fats and oils," Food Reviews International, vol. 17, no. 3, pp. 249–290, 2001.

[23] D. W. Lachenmeier, E. Humpfer, F. Fang et al., "NMR-spectroscopy for nontargeted screening and simultaneous quantification of health-relevant compounds in foods: the example of melanine," Journal of Agricultural and Food Chemistry, vol. 57, no. 16, pp. 7194–7199, 2009.

[24] E. Capuano, A. Lommen, S. van Ruth, A. de la Dura, M. Rozijn, and S. van Ruth, "Wild salmon authenticity can be predicted by 1H-NMR spectroscopy," Lipid Technology, vol. 24, no. 11, pp. 251–253, 2012.

[25] M. Gerber, M.-C. Boutron-Ruault, S. Hercberg, E. Riboli, A. Scalbert, and M.-H. Siess, "Food and cancer: state of the art about the protective effect of fruits and vegetables," Bulletin du Cancer, vol. 89, no. 3, pp. 293–312, 2002.

[26] A. Arora, R. Sen, and J. Singh, "Fatty acid composition of Delonix regia (Gulmohar) seed oil from arid zone of Rajasthan," Journal of the Indian Council of Chemists, vol. 27, no. 2, pp. 150–152, 2010.

[27] A. Arora and R. Sen, "Determination of fatty acids in plant seeds of leguminosae family from arid zone of Rajasthan," Asian Journal of Chemistry, vol. 22, no. 3, pp. 2474–2476, 2010.

[28] A. Adewuya, R. A. Onderine, B. V. S. K. Rao, R. B. N. Prasad, and B. Anjaneyulu, "Chemical component and fatty acid distribution of Delonix regia and Peltophorium pterocarpum seed oils," Food Science and Technology Research, vol. 16, no. 6, pp. 565–570, 2010.

[29] A. Adewuya and R. A. Onderine, "Analysis of the mineral nutrient, chemical composition and distribution of fatty acids in the lipid classes of the seed oils of underutilized legumes from Nigeria," Rivista Italiana delle Sostanze Grasse, vol. 88, no. 2, pp. 89–96, 2011.

[30] M. Ashraduzzaman, M. A. Alam, S. Khatun, S. Banu, and N. Absar, "Vigna unguiiculata linn. Walp. Seed oil exhibiting anti-diabetic effects in alloxan induced diabetic rats," Malaysian Journal of Pharmaceutical Sciences, vol. 9, no. 1, pp. 13–23, 2011.

[31] V. Thoss, P. J. Murphy, R. Marriott, and T. Wilson, "Triacylglycerol composition of British bluebell (Hyacinthoides non-scripta) seed oil," RSC Advances, vol. 2, no. 12, pp. 5314–5322, 2012.

[32] W. Kamm, F. Dionisi, C. Hischenhuber, and K.-H. Engel, "Authenticity assessment of fats and oils," Food Reviews International, vol. 17, no. 3, pp. 249–290, 2001.

[33] D. W. Lachenmeier, E. Humpfer, F. Fang et al., "NMR-spectroscopy for nontargeted screening and simultaneous quantification of health-relevant compounds in foods: the example of melanine," Journal of Agricultural and Food Chemistry, vol. 57, no. 16, pp. 7194–7199, 2009.

[34] E. Capuano, A. Lommen, S. van Ruth, A. de la Dura, M. Rozijn, and S. van Ruth, "Wild salmon authenticity can be predicted by 1H-NMR spectroscopy," Lipid Technology, vol. 24, no. 11, pp. 251–253, 2012.
[35] A. Rohman and Y. B. Che Man, “Application of gas chromatography and FTIR spectroscopy for analysis of palm oil in adulterated sesame oil,” European Journal of Lipid Science and Technology, vol. 133, pp. 522–527, 2011.

[36] G. M. S. El-Bahy, “FTIR and Raman spectroscopic study of Fenugreek (Trigonella foenum graecum L.) seeds,” Journal of Applied Spectroscopy, vol. 72, no. 1, pp. III–116, 2005.

[37] T. M. Bray and W. J. Bettger, “The physiological role of zinc as an antioxidant,” Free Radical Biology and Medicine, vol. 8, no. 3, pp. 281–291, 1990.

[38] A. S. Prasad, “Zinc: an antioxidant and anti-inflammatory agent: role of zinc in degenerative disorders of aging,” Journal of Trace Elements in Medicine and Biology, vol. 28, no. 4, pp. 364–371, 2014.

[39] S. R. Powell, “The antioxidant properties of zinc,” Journal of Nutrition, vol. 130, no. 5, pp. 1447S–1454S, 2000.