Physicochemical characterization of *Grewia* species biopolymer, a potential coagulation-flocculation agent

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Powdered *Grewia* species barks was extracted in water and one part of the extract was precipitated with absolute ethanol. Both the crude water extract and the ethanol precipitate were freeze dried, pulverized into powder and subjected to physicochemical analyses. Amongst others, proximate composition, morphology and metal contents by Scanning Electron Microscopy with Energy Dispersive X-Ray (SEM-EDX), functional group by Fourier-transform infrared spectroscopy (FTIR), crystallinity by X-ray powder diffraction (XRD), thermal behavior via Differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA). The molecular mass of the ethanol precipitate was appraised through viscosity measurements and the Huggins plot. Results show that both the crude extract and the ethanol precipitate were rich in polysaccharide type polymers. However, precipitation led to a reduction in the metal contents confirmed by the ash contents and the EDX analysis as well as the absence of sharp peaks on the XRD plots as was the case of crude extracts. Precipitation led to a decrease in the lipid and protein contents initially present in the crude *Grewia* spp. extracts. XRD and SEM analyses revealed that *Grewia* spp. extract and the precipitate were both amorphous with a porous microstructure. Results also showed that *Grewia* spp. biopolymer has functional groups which can serve as active sites for the attachment of colloidal particles.

Key words: *Grewia* species, biopolymer, extraction, precipitate, characterization.

INTRODUCTION

Due to their effectiveness, synthetic coagulants/flocculants such as aluminium sulphate, iron chloride, polyacrylamide, and polyaluminium chloride are most commonly used in the coagulation-flocculation unit operation (Okaiyeto et al., 2016; Dihang et al., 2008; Okuda et al., 2001). However, their use results in the production of large quantities of metal-contaminated sludge, and in addition, aluminium and iron residues in treated water has been linked to the development of certain diseases, as Alzheimer’s and some cancers (Okaiyeto et al., 2016; Sotero-Santos et al., 2007; Ruden, 2004; Campbell, 2002). To overcome this issue,
some plants extracts like *Moringa oleifera*, *Hibiscus esculentus* (Okra), *Strychnos potatorum* and *Bridelia Ferruginea* have shown great potentials to serve as coagulation/flocculation agents (Georgiadis et al., 2011; Pritchard et al., 2010; Kolawole et al., 2007). Plants extracts used as natural coagulants/flocculants are macromolecules which could be extracted from different parts of plants (barks, leaves, roots, among others) (Daza et al., 2016; Babu et al., 2013; Yang et al., 2011). The bark extracts of *Grewia* species plants are traditionally used as a clarifying agent for beverages, domestic effluents and surface water in the northern part of Cameroon. Given that the active compound of a biocoagulant/flocculant can be a protein, a polysaccharide or a combination of both, there is need to investigate the composition and properties of substances from biological origin having coagulation/flocculation properties as it shall provide information on the nature of these extracts in order to justify its application in water treatment (Miller et al., 2008).

There is not enough information on the nature of the molecules responsible for the coagulant/flocculant properties of *Grewia* spp. biopolymer, thus the extraction and partial purification (precipitation with absolute ethanol) of the crude extracts prior to its characterization was the main objective in this study.

**MATERIALS AND METHODS**

**Sampling and extraction of *Grewia* spp. biopolymer**

*Grewia* spp. barks were collected from Mokolo (North region of Cameroon), transported to the laboratory, dried and stored at room temperature. Crude *Grewia* spp. biopolymer was extracted following the method of Somboonpanyakul et al. [(2006)] with some modification. The dried and pulverized bark of *Grewia* spp. was dispersed in milli Q water (1:80 w/v, pH 4) at 50°C for 4 h. The fibrous material from the dispersed mucilage is removed by straining through centrifugation at 3894 g for 20 min. Thereafter, the crude mucilage was precipitated with 2 volumes of 95% absolute ethanol and freeze-dried. The extraction process is as shown in Figure 1. The *Grewia* spp. biopolymer extraction yield was obtained using the following equation:

\[
yield = \frac{m}{m_i} \times 100
\]

(1)

Where ‘m’ is the biopolymer mass after extraction and ‘mi’ the
biopolymer mass before extraction.

Characterization of Grewia spp. biopolymer

Proximate composition of Grewia spp. biopolymer

Proximate composition (protein, lipids and ash contents) of Grewia spp. biopolymer was determined according to the methods of the AOAC (1975). Total sugar was determined by Anthrone sulfuric acid reaction. The difference between total and free sugar content of samples represented the polysaccharide content which was assimilated to gum content.

Determination of the viscosity of Grewia spp. biopolymer extract

Powder samples of Grewia were dissolved in milli Q water in order to obtain samples at various concentrations (0.005, 0.01, 0.015, and 0.02 g/dL). The viscosity of Grewia spp. biopolymer was measured with an Ostwald capillary viscometer. 15 ml of extracts was introduced into the viscometer which was immersed in a thermostatic water bath at 25°C. The efflux time of the biopolymer extract at various concentrations was measured (t) and that of water was also measured (t0). The relative viscosity (\(\eta_{rel}\)) was calculated thus:

\[
\eta_{rel} = \frac{t}{t_0}
\]  

(2)

Specific viscosity (\(\eta_{sp}\)) was also determined according to:

\[
\eta_{sp} = \eta_{rel} - 1
\]

(3)

Reduced viscosity (\(\eta_{red}\)) is given by:

\[
\eta_{red} = \frac{\eta_{rel}}{C}
\]

(4)

where C is the concentration of Grewia spp. biopolymer solution in (g/dL).

Functional groups

The functional groups of the Grewia spp. biopolymer was determined by infrared spectroscopy. Infrared spectra of Grewia spp. biopolymer samples were recorded with a Fourier Transform Infrared Spectrometer (Perkin Elmer Spectrum GX). Approximately, 1 mg of sample was mixed with 25 mg KBr and both were ground together in an agate mortar. Thereafter, a pellet was prepared using a 5 tons caver type press. The spectra were recorded in the 4000 to 400 cm\(^{-1}\) wavenumber range.

Powder X-ray diffraction

X-ray diffraction was carried out on a Panalytical Empyrean (p-Xrd) diffractometer, Netherland. The equipment used Cu target and a pixel 3D solid state X-ray detector. Powder samples were placed on a sample holder and inserted into the X-ray machine. Samples were analyzed over an angular range of 2 Theta: 5 - 89.9823° with a step size of 0.0130 with a scan step time of 18.8700 s. The X-ray source was Cu K-\(\alpha_1\) (1.54060 Å) and Cu K-\(\alpha_2\) (1.54443 Å).

Scanning electron microscopy with energy dispersive X-rays (SEM-EDX)

A pinch of Grewia spp. biopolymer was suspended in 100 \(\mu\)L ethanol and agitated for proper dispersion of the biopolymer. This was closely followed by the addition of 900 \(\mu\)L of MilliQ water followed by vortexing and sonication for 30 s. The sample was then placed on aluminium stubs and allowed to dry in desiccator overnight. SEM Images were collected with a JEOL, JSM-7100F Field Emission Scanning Electron Microscope (Model SM 71031SE2A) Japan.

Thermal properties of Grewia spp. biopolymer

Thermal degradation of the Grewia spp. biopolymer was studied on a Thermo-gravimetric Analyzer (NETZSCH, TG 209 F1 Libra, Germany). Approximately, 1 mg of sample was introduced into an aluminium oxide crucible and heated within a temperature range of 35 to 500°C at a rate of 5K/min under nitrogen atmosphere. Differential Scanning Calorimetry (DSC) (NETZSCH, DSC 204F1 Phoenix, Germany) was also used to study the thermal properties of the Grewia spp. biopolymer. Known weights of powder Grewia spp. biopolymer was loaded on an aluminium pan and the energy level of the samples was scanned in the range -20 to 500°C under nitrogen atmosphere with a temperature gradient of 5°C/min.

RESULTS AND DISCUSSION

Proximate composition of the Grewia spp. biopolymer

Results of the proximate composition of Grewia spp. biopolymer before and after purification are presented in Table 1. Chemical analysis shows that the purified biopolymer is composed approximately of 4% of protein, 42% of total sugar and 40% of gum. The sugars represent the main components, among which gums defined as polysaccharides are predominant. Our results are close to those obtained by Akdowa et al. (2014) and Saidou et al (2011). Results also show that pH does not have significant effect on the proximate composition of Grewia spp. biopolymer. The extraction and purification procedure used to isolate biopolymer appears efficient, since the most of proteins, lipids and the mineral present on crude biopolymer were removed after purification. This could lead to an improvement in the coagulation/ flocculation performance of Grewia spp. biopolymer.

Grewia spp. biopolymer extraction yield at different pH

In order to study the influence of pH on the Grewia spp. biopolymer extraction yield, the extraction was carried within the pH range of 2 to 7, and the results are presented in Figure 2. The extraction yields of Grewia spp. biopolymer at pH
Table 1. Proximate composition of the *Grewia* spp. Biopolymer.

| Composition (g/100 g MS) | Crude *Grewia* powder | *Grewia* spp. biopolymer pH 2 | *Grewia* spp. biopolymer pH 4 | *Grewia* spp. biopolymer pH 5 | *Grewia* spp. biopolymer pH 7 |
|--------------------------|------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| Sugar content            | 53.02 ± 0.06           | 44.41 ± 0.23                  | 43.41 ± 0.08                  | 41.61 ± 0.1                   | 39.25 ± 0.15                  |
| Gum content              | 52.79 ± 0.05           | 42.41 ± 0.15                  | 43.36 ± 0.07                  | 40.21 ± 0.2                   | 37.41 ± 0.25                  |
| Protein content          | 8.58 ± 0.05            | 2.5 ± 0.07                    | 3.66 ± 0.07                   | 4.45 ± 0.5                    | 5.70 ± 0.37                   |
| Lipid content            | 3.23 ± 0.08            | -                             | -                             | -                             | -                             |
| Ash content              | 14.6 ± 1.25            | 5.3 ± 0.09                    | 7.6 ± 0.08                    | 7.9 ± 0.15                    | 9 ± 0.95                     |

Figure 2. Influence of pH on *Grewia* spp. biopolymer extraction yield.

2, 4, 5, and 7 calculated after freeze drying are 35.73 ± 0.67, 36 ± 1.28, 36.74 ± 1.60, and 35.83 ± 1.67%, respectively. We note that pH does not have significant influence on the extraction yield of *Grewia* spp. Akdowa et al. (2014) also showed during their work that pH does not have significant influence on the viscosity and extraction yield of *Grewia mollis* gum. The extraction yield obtained is close to those obtained by Nep et al. (2010).

**Influence of pH and biopolymer concentration on the viscosity**

Figure 3 shows the pH and biopolymer concentration effects of the *Grewia* spp. biopolymer viscosity. Results display the increase of the viscosity with the biopolymer concentration irrespective of the pH. The gradual increase of viscosity as the amount of polymer increases could be due to the fact that Grewia spp. biopolymer displays a non-Newtonian flow behavior (Huang et al., 2019; Kamal et al., 2015; Jamal, 2012). That behavior is close to the work carried by Nep et al. (2010).

It is also noted that the pH has no significant effect on the viscosity. For the same biopolymer concentration, the viscosity of the *Grewia* spp. extract shows little change over the range of pH 2 to 7. This sharp reduction in viscosity may be due either to chemical degradation in acid milieu, or to a change in molecular conformation, which may or may not be reversible (Sorbie et al., 1992). Our results are in agreement with those obtained by Akdowa et al. (2014).

The intrinsic viscosity was determined graphically from the Huggins plot (Figure 4). From that figure the intrinsic viscosity obtained was 16.5 dL/g. Morris (1990), proposes a classification of the polymers size according to their intrinsic viscosities and indicates that the intrinsic viscosities between 5 and 25 dL/g correspond to the high molecular mass polymers. Therefore, based on our results, *Grewia* spp. biopolymer falls into this range and is considered as high molecular mass biopolymer, suggesting that it can favor adsorption and bridging effect during coagulation-flocculation, encourage the densely packed aggregate nature of floc, and thus enhance floc settling velocity (Li et al., 2006; Niu et al., 2013; Li et al., 2013). These observations are in agreement with our previous works (Kameni et al., 2019).

**Functional groups of *Grewia* spp. biopolymer by FTIR**

The FTIR spectrum of *Grewia* spp. biopolymer before and after purification is presented in Figure 5. Spectra
exhibited the typical bands and peak characteristic of polysaccharides (Kameni et al., 2019). There was no major difference between spectra obtained before (a) and after (b) purification. The broad band at 3406 cm⁻¹ indicates the presence of hydroxyl (-OH) groups due to moisture but could also arise from the hydroxyl of sugar rings. The band at 2933 cm⁻¹ indicates the presence of sugars (galactose, arabinose and rhamnose); also, the presence of alkane C-H stretch and aldehyde C-H stretch. The glucuronic acids have specific vibrations such as the band at 1428 cm⁻¹ due to COOH group. The band at 1255 cm⁻¹ represents C-O-H bend of CH₂OH. The peak obtained at 1734 cm⁻¹ results from stretching mode C=O stretch (Filippov, 1992). The wave numbers between 800 and 1200 cm⁻¹ represent the fingerprint region for carbohydrates. All these groups can serve as active sites for the attachment of colloidal particles. The FTIR spectrum of Grewia spp. biopolymer is similar to the one of Chitosan and Okra gum used for the aggregation of colloidal particles (Li et al., 2013; Freitas et al.,

![Figure 3](image-url). Influence of Grewia spp. biopolymer concentration on the viscosity of at different pH.

![Figure 4](image-url). Huggins plot of Grewia spp. Biopolymer.

\[ y = 1980 \times + 16.5 \]

\[ R^2 = 0.94 \]
2015; Ani et al., 2012).

**Grewia** spp. biopolymer crystalline structure

XRD analysis was applied to detect the crystalline structure of the **Grewia** spp. biopolymer (Figure 6). The XRD pattern shows that **Grewia** spp. biopolymer before purification (a) is consisted of amorphous and crystalline structure. It shows peaks at 2 theta within the range of 8 to 41°C. After purification, the XRD pattern shows zero peak, which suggests that purified **Grewia** spp. biopolymer is consisted of amorphous structure. The XRD graph of **Grewia** spp. biopolymer is comparable to the one of Okra gum used for the destabilization of colloidal suspension (Freitas et al., 2015).

**Scanning electron microscopy (SEM) pattern of** **Grewia** spp. biopolymer

SEM images of biopolymer before (a, b) and after (c, d) purification are represented in Figure 7 at different magnifications. In both case the microphotographs are indicative of an amorphous material. The particles are mostly seen as aggregates of irregular shapes. SEM and XRD analyses confirm that **Grewia** spp. biopolymer is an amorphous material.

**Electron dispersive spectroscopy pattern of** **Grewia** spp. biopolymer

EDX was carried out to detect the elements present at the surface of a particular area of **Grewia** spp. biopolymer. The EDX spectrum of biopolymer before (a) and after purification (b) is presented in Figure 8. Result shows that some elements present on the surface of crude biopolymer disappeared after purification. We can observe that elements like Mn and Sr present on the surface of crude biopolymer are absent after purification. This suggests that the purification process used is efficient to reduce the metal content of biopolymer. The
Figure 7. SEM images of Grewia spp. biopolymer before (a, b) and after purification (c, d).

Figure 8. Energy dispersive spectroscopy pattern of Grewia spp. biopolymer before (a) and after purification (b).

major elements present in Grewia spp. biopolymer are K, Ca, Cl, C, Mg and O.

Thermal behavior of Grewia spp. biopolymer

Thermal stability of the polymer is an important property that could make the material fit for industrial applications where material is thermally processed. Thermal stability analysis of polymer material is helpful in the selection of materials with the best properties for specific used. Thermal analysis of Grewia spp. biopolymer samples were carried out with Differential Scanning Calorimetry (DSC) and Thermal Gravimetric Analysis (TGA).

Differential scanning calorimetry

The results of DSC analysis of Grewia spp. biopolymer are presented in Figure 9. The analysis reveals that the glass transition temperature is around 140.3°C. Consequently, Grewia spp. biopolymer occurs in a glassy state at room temperature (Nurul et al., 2014). Grewia spp. biopolymer is preferably stored at or below room temperature in a dry environment to reduce occurrence of any chemical changes to the structure of molecules, thus
conserving its quality and functionality. The major intense peak recorded in the DSC graph is an endothermic transition. This may be due to moisture desorption. All those observations are close to results obtained by Nep et al. (2010) and Nurul et al. (2014).

**Thermogravimetric analysis**

The results of TGA analysis of *Grewia* spp. biopolymer are displayed in shown Figure 10. The first mass loss taking place between 30 and 125°C may be attributed to the loss of adsorbed and structural water of biopolymer (Bothara et al., 2012), or due to desorption of moisture as hydrogen bound water to the biopolymer structure. This resulted in a weight loss of about 16.17%. The second weight loss event, with an onset of over 290°C, can be attributed to thermal decomposition of the biopolymer.

From the results, we can conclude that *Grewia* spp. is a thermal stable biopolymer.

**Conclusion**

The extracted biopolymer was purified and characterized and the results revealed that both the crude extract and the ethanol precipitate were rich in polysaccharide type polymers. The results also revealed that the purification process led to a reduction in the lipid, protein and metal contents of crude *Grewia* spp. biopolymer. Physicochemical characterization showed that *Grewia* spp. biopolymer has a fairly similar physicochemical composition to those of some biopolymers used as coagulation-flocculation agents principally the Okra gum. The use of *Grewia* spp. biopolymer in water treatment as a natural coagulant/flocculant may be an alternative with
numerous advantages over chemical agents, mainly biodegradability, low toxicity and low residual sludge production. These coagulants are safe to human health and the environment.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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