Anti-inflammatory and antioxidant activities of extracts of Reissantia indica, Cissus cornifolia and Grosseria vignei

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Abstract: Unpleasant side effects associated with prolonged use of current anti-inflammatory drugs have necessitated a need for new drugs with limited side effects. Plants rich in antioxidants have been suggested as potential sources of anti-inflammatory compounds. Thus, the anti-inflammatory and antioxidant activities of extracts of Reissantia indica, Grosseria vignei and Cissus cornifolia—medicinal plants with widespread use in folkloric medicine in Ghana—were evaluated in this study. The phytochemical composition and total phenolic content (TPC) of these extracts were determined using standard methods. Antioxidant potential was screened using the ferric reducing antioxidant activity, nitric oxide and hydrogen peroxide scavenging, and the phosphomolybdenum assays. The anti-inflammatory activities were evaluated using an in vivo assay. Alkaloids, flavonoids, terpenoids, glycosides and coumarins were present in extracts of all three plants. The TPC of Reissantia indica (38.44 µg/g GAE) was twice that of Grosseria vignei (19.12 µg/g GAE) whereas Cissus cornifolia (7.59 µg/g GAE) had the lowest TPC. In all antioxidant tests, activities of the plant extracts varied in the order: Reissantia indica > Grosseria vignei > Cissus cornifolia, which was in agreement with the TPC data. All extracts exhibited potent anti-inflammatory activities, with the dose of extract required to cause half-maximal reduction in edema (ED50) below 80 mg/kg. Reissantia indica was the most potent anti-inflammatory extract with an ED50 of 47.23 mg/kg. The ethanol extracts of Reissantia indica, Grosseria vignei, and Cissus cornifolia thus exhibited potent anti-inflammatory and antioxidant activities and may be important sources of novel antioxidant and anti-inflammatory agents.

Public Interest Statement

In Ghana, medicinal plants play a critical role in the treatment of various ailments. Three plants commonly used in this endeavor are Reissantia indica, Cissus cornifolia and Grosseria vignei. They are used to manage diseased conditions associated with inflammation. However, scientific validation of the extracts of these plants is absent. The results of this work show clearly that the extracts of Reissantia indica, Cissus cornifolia and Grosseria vignei are very good anti-inflammatory agents and do possess excellent antioxidant activities as well. This therefore justifies their use in folkloric medicine for the treatment of inflammation-related diseased conditions. Future isolation of the active compounds in these plants could provide important leads for the development of new drugs.
1. Introduction
Human diseases that occur as a result of invasion of the body by pathogens and toxins, as well as immune regulation, stimulate a cascade of inflammatory events in the body. These inflammatory events are designed to initiate and enhance healing of body tissues (Nathan, 2002). The release of mast cell proteases, for instance, is followed by a cascade of redox events induced by the release of reactive oxygen species (ROS) and free radicals that are useful for cellular signal transduction and defense against pathogens but become deleterious when unregulated. The uncontrolled progression of such pro-inflammatory activities as part of the human innate immune mechanism has been associated with oxidative stress and other diseased conditions such as cancer, diabetes, hypertension, septic shock, asthma, arthritis, arteriosclerosis, Parkinson’s and Alzheimer’s diseases. As such, the control of pro-inflammatory processes and chronic inflammation has been of increasing interest, owing to possibilities of reducing or eliminating major neurodegenerative disorders (Caughey, 2016, Allavena et al., 2008).

Antioxidants modulate the oxidant–antioxidant profile of body systems by nullifying pro-oxidant molecules (Ajith et al., 2017). Antioxidant use is associated with reduced production of ROS, free radicals and reduced pre-disposition to lipid peroxidation, oxidative stress, post-translational modification of proteins, and DNA damage. Most of these defensive antioxidants are available from plant and dietary sources (Sagin & Sozmen, 2004). Synthetic antioxidants for controlling undesirable redox events are available at high cost, and mostly suffer set-backs of unavailability and side effects. As a result of these challenges, natural antioxidants have received attention over time, since they do not possess the side effects associated with their synthetic counterparts, are cheaper and ever-present in many plants (Rivera et al., 2013). Also, anti-inflammatory agents used to augment the role of innate immunity against inflammatory disorders are classified as steroidal and non-steroidal anti-inflammatory agents and many possess unpleasant side effects arising from prolonged use. The prolonged use of non-steroidal anti-inflammatory drugs (NSAIDs) such as aspirin, and coxibs, includes increased risk of gastrointestinal and cardiovascular complications (Sostres et al., 2010). Natural product-based preparations have been suggested as a potential solution to some of these challenges.

Plant natural products are the major sources of remedies for most human diseases. They are prepared in the form of decoctions in most herbal and ethnomedicinal practices worldwide, especially in Africa and Asia. Natural products are usually the first point of call in the management of acute and chronic health complications owing their predilection to availability, efficacy and reported minimal side effects (Oguntibeju, 2018, Welz et al., 2018). In plants, an array of phytochemicals exists in synergy to elicit observed pharmacological effects. The most characterized phytochemicals for antioxidant and anti-inflammatory activities are alkaloids, polyphenols, terpenoids, and flavonoids such as anthocyanin and flavone. Plants possessing these phytochemicals have served as sources of potent anti-oxidant and anti-inflammatory agents (Fang, 2014, Liu, 34795-34855, 2004). Though several studies have focused on plants, there still exist a vast number of flora unexplored with regard to Ghana’s herbal medicine (Oguntibeju, 2018). Scientific validation for the use of most of these plants in traditional herbal medicine is also absent in the literature and needs to be addressed.

*Reissantia indica* (Wild.) N.Hallé [Family Celastraceae], *Cissus cornifolia* (Baker) Planch. [Family Vitaceae] and *Grosseria vignei* [Family Euphorbiaceae] are among the most utilized plants in herbal preparations on the Ghanaian herbal market and other parts of the world (Anim et al., 2012). However, reports on the scientific validation of their application in ethnomedicine are very limited in the literature. Quite recently, the ethanolic extract of the aerial parts of *Reissantia indica* has been shown to be effective against the progression of breast cancer (Gayathri et al., 2018). The
butanolic and methanolic leaf extracts of *Cissus cornifolia* have also been investigated for phytochemical composition, anti-convulsant and some other neuro-pharmacological potential in mice with interesting results (Musa et al., 2008, Yaro et al., 2015). As a result of these, we have evaluated the phytochemical profile, anti-oxidant activities and anti-inflammatory potential of the ethanolic extracts of *Reissantia indica*, *Cissus cornifolia*, and *Grosseria vignei*. We report herein that, alkaloids, triterpenoids, glycosides and coumarins were present in all plant extracts, with flavonoids additionally present in *Reissantia indica*. For all extracts studied, total phenolic content in extracts of *Reissantia indica* was highest, followed by *Grosseria vignei* and *Cissus cornifolia*. All plant extracts possessed excellent antioxidant and anti-inflammatory potentials. This study therefore provides a scientific justification for the use of these plants in herbal medicinal preparations targeted at diseased conditions which involve inflammation, such as wound healing.

2. Methods

2.1. Sample collection and authentication

The plant samples were obtained from Akropong Mampong, Ghana in September 2017 and were authenticated as *Reissantia indica* (KNUST/HM1/2017/L039), *Cissus cornifolia* (KNUST/HM1/2017/T018) and *Grosseria vignei* (KNUST/HM1/2017/L040) at the Department of Pharmacognosy, KNUST. Table 1 describes the plants used in this study and their local indications.

2.2. Solvent extraction

The collected plant parts were cleaned, air-dried, pulverized and homogenized. A 200 g sample was then cold-macerated with 1 L of 70% ethanol. The extracts obtained were centrifuged to obtain the supernatant which was concentrated using the rotary evaporator (N-1110, Cole Parmer, China). The crude extracts were air-dried to remove solvent traces and then used to prepare suitable stock concentrations as required (Laryea & Borquaye, 2019).

2.3. Phytochemical analysis

The phytochemical constituents in the extracts of *Reissantia indica*, *Cissus cornifolia*, and *Grosseria vignei* were determined qualitatively according to standard procedures described elsewhere (Adia et al., 2016, Harborne, 1998). Phytochemicals tested included alkaloids, flavonoids, saponins, tannins, glycosides, terpenoids, triterpenoids and coumarins.

2.4. Total phenolic content

Total phenolic content (TPC) was determined according to the Folin and Ciocalteau’s method, as described previously by Gyesi and coworkers. Gallic acid was used as a standard and was prepared in methanol. Different concentrations of plant extracts were made in methanol. An aliquot of each sample (0.5 mL) was mixed with 10% Folin-Ciocalteau’s reagent (2.5 mL, 10%) and sodium carbonate (2 mL, 7.5%). The mixture was made to stand for at room temperature for half an hour before the absorbance was read at 760 nm (UV-1280 UV-Vis Spectrophotometer, Japan). A calibration curve of standard gallic acid was obtained by using gallic acid in place plant extract. Triplicate determinations were made in all experiments. The TPC for each extract was derived from the gallic acid calibration curve and expressed as gallic acid equivalent (GAE) (Gyesi et al., 2019).

3. Antioxidant activities

3.1. Ferric reducing antioxidant power determination

A modified ferric reducing antioxidant power (FRAP) assay procedure was used (El Jemli et al., 2016). Ascorbic acid and butylated hydroxyl toluene (BHT) were used as reference standards. Briefly, phosphate buffer (2.5 mL, 0.2 M, pH 6.6) and potassium ferricyanide (K₃[Fe(CN)₆], 2.5 mL, 1% w/v), were added to 1 mL of different concentrations of the extracts and reference standards and incubated for 20 minutes at 50°C to convert the ferricyanide to ferrocyanide. Addition of trichloroacetic acid (2.5 mL, 10% w/v) terminated the reaction. The mixture was centrifuged (SciSpin ONE, UK) for 10 minutes at 4000 rpm. The upper layer (2.5 mL) was mixed with equal
| Botanical Name       | Family      | Part Used      | Local Indications               | Extraction Yield (%) |
|---------------------|-------------|----------------|---------------------------------|---------------------|
| Grosseria vignei    | Euphorbiaceae | Leaves and twigs | Wound healing/fever              | 7.3                 |
| Cissus cornifolia   | Vitaceae    | Twigs          | Hernia/stomach-ache/malaria     | 4.7                 |
| Reissantia indica   | Celastraceae | Leaves and twigs | Malaria/body pains               | 6.2                 |
volume of distilled water and 0.1% FeCl₃ (0.5 mL). The absorbance of the resulting mixture was measured at 700 nm (UV-1280 UV-Vis Spectrophotometer, Japan). The IC₅₀ values for samples and standards were derived from dose–response curves generated from the absorbance data.

3.2. Nitric oxide scavenging activity
At physiological pH, sodium nitroprusside spontaneously generates nitric oxide (NO) in an aqueous solution. Nitrite ions (NO₂⁻) are generated by the interaction of NO with oxygen. The amount of NO₂⁻ generated can then be estimated by the Griess Illosvoy reagent. When present, agents that scavenge NO will compete with oxygen, thus leading to a reduction in the amount of NO₂⁻ produced. This forms the basis of the nitric oxide scavenging assay (Green et al., 1982, Marocci et al., 1994). To evaluate the nitric oxide scavenging capabilities of the extracts, sodium nitroprusside (10 mM, 2 mL), phosphate buffer saline (0.5 mL), and extract (6.0 to 0.005 mg/mL, 0.5 mL) or standard solution (0.2 to 0.0015 mg/mL, 0.5 mL) were mixed together in a test tube and made to stand at 25 °C. A similar reaction mixture that contained ethanol, instead of extract, served as the blank. After 2 hours, an aliquot of the reaction mixture (0.5 mL) was added to 1 mL sulphanilic acid reagent [prepared as 1.0% (w/v) sulphanilamide in 2.5% (v/v) orthophosphoric acid]. The resulting solution was made to stand for 5 minutes to facilitate complete diazotization. Thereafter, 1 mL of naphthylethylenediamine hydrochloride (0.1%) was added to the solution, mixed, and incubated for another half an hour. This led to the formation of a pink-colored solution. The absorbance of all solutions (blank or extract) was then measured at 540 nm (UV-1280 UV-Vis Spectrophotometer, Japan). The nitric oxide scavenging activity was estimated from Equation (1);

\[
\text{Percent NO Scavenged} = \frac{A_{\text{control}} - A_{\text{sample}}}{A_{\text{control}}} \times 100
\]

where \(A_{\text{control}}\) is blank solution absorbance and \(A_{\text{sample}}\) is the extract absorbance.

Dose–response curves were generated by plotting Percent NO Scavenged against concentration and IC₅₀ values (concentration of extract required to scavenge 50% of generated NO) were derived from the dose–response curves.

3.3. Hydrogen peroxide (H₂O₂) scavenging
Hydrogen peroxide scavenging activity was determined using a similar method described earlier (Gyesi et al., 2019, Mukhopadhyay et al., 2016, Borquaye et al., 2016). Ascorbic acid at 500 µg/mL used as a standard. The percentage of hydrogen peroxide scavenged for both extracts and the standard ascorbic acid was evaluated from Equation (2).

\[
\text{Percent H₂O₂ Scavenged} = \frac{A_{\text{control}} - A_{\text{sample}}}{A_{\text{control}}} \times 100
\]

3.4. Evaluation of total antioxidant capacity
The sum total of fat-soluble and water-soluble anti-oxidants producing a total antioxidant capacity of extracts was evaluated by the phosphomolybdenum (PM) assay described elsewhere (Gyesi et al., 2019). The total antioxidant capacity was expressed as ascorbic acid equivalent (AAE) based on the ascorbic acid calibration curve. All experiments were performed in triplicates and the data expressed as Mean ± SD.

3.5. Anti-inflammatory activity
The carrageenan-induced edema model of inflammation in 7-day-old chicks was used to evaluate anti-inflammatory activity. The method used has been described in detail in our earlier publications (Borquaye et al., 2017, Ofori-Baah et al., 2019). Group sample size of five randomly selected chicks was used in this study. Animal handling followed protocols approved by the National Institute of Health and the institutional animal care and use guidelines approved by the Ethics Committee of the Department of Pharmacology, KNUST. Diclofenac (25 mg/kg) was used as the positive control. Extracts were evaluated at doses of 50 mg/kg, 100 mg/kg and 150 mg/kg. All drugs and extracts were administered in volumes not exceeding 100 mL/kg.
3.6. Data analysis
All data were analyzed using Microsoft Excel and GraphPad Prism version 6 (GraphPad Software, San Diego, CA, USA). Differences in means of treatments were by one-way analysis of variance (ANOVA) followed by Dunnett’s post hoc test.

4. Results

4.1. Phytochemical profiling
The phytochemicals tested in this study included alkaloids, flavonoids, terpenoids, glycosides, tannins, coumarins and saponins (Table 2). Analysis of Reissantia indica extract indicated the presence of alkaloids, flavonoids, terpenoids, glycosides, tannins, and coumarins. That of Cissus cornifolia revealed the presence of alkaloids, flavonoids, terpenoids, triterpenoids, glycosides, coumarins and saponins. Grosseria vignei possessed all phytochemicals tested.

4.2. Total phenolic content
The total phenolic content of each extract was tested at 500 µg/mL and the results are presented in Table 3. The total phenolic content of Reissantia indica (38.44 ± 1.21 µg/g GAE) was about that of Grosseria vignei (19.12 ± 0.83 µg/g GAE) whereas Cissus cornifolia contained the least amount of phenolic compounds, with a total phenolic content of 7.59 ± 0.83 µg/g GAE.

4.3. Antioxidant activity
The ability of plant extracts to reduce Fe (III) to Fe (II) was tested with the reducing power activity assay to evaluate their redox regulatory potential. The results are presented in Table 4. Reissantia indica possessed the highest ferric reducing potential, with only 357.8 ± 0.68 µg/mL of extract required to reduce 50% of Fe(III) to Fe(II). Grosseria vignei demonstrated moderate reducing power with an IC50 value of 1637 ± 4.3 µg/mL. Of the extracts, Cissus cornifolia demonstrated the weakest reducing power ability, with an IC50 > 5000 µg/mL. Results of the nitric oxide scavenging activities of the extracts are shown in Table 4. Reissantia indica exhibited excellent scavenging activity with an IC50 of 320 ± 3.2 µg/
mL. Both Grosseria vignei and Cissus cornifolia only moderately scavenged the nitric oxide radicals, with the IC$_{50}$ of both extracts greater than 1000 µg/mL. In the hydrogen peroxide scavenging assay, both Reissantia indica and Grosseria vignei exhibited similar scavenging potentials. The two extracts, at 500 µL, were able to scavenge over 40% of the hydrogen peroxide available. In comparison, the standard ascorbic acid at a similar concentration scavenged twice that amount, with about 85% of available hydrogen peroxide scavenged. At the same concentration, the scavenging activity of Cissus cornifolia was much lower, with the percentage of hydrogen peroxide scavenged being only 14.3 ± 0.43%. The results of the hydrogen peroxide scavenging assay are also shown in Table 4. The phosphomolybdenum assay was used to assess the total antioxidant capacity of the extracts. The total antioxidant capacity (TAC) of Reissantia indica was much greater than those Grosseria vignei and Cissus cornifolia. The TAC for Reissantia indica was 66.03 ± 2.13 µg/g AAE whereas that for Grosseria vignei and Cissus cornifolia were 48.56 ± 1.32 and 13.63 ± 0.66 µg/g AAE, respectively, as shown in Table 3.

### 4.4. Anti-inflammatory activity

Subcutaneous administration of carrageenan resulted in a noticeable increase in chicks’ paw size; an indication of induced inflammation. In the control set of chicks, maximum inflammation was observed after 30 min and this persisted until the 2-hour mark. This reduced very slowly to the third hour, showing immune response to abate inflammation. Oral administration of the extracts (Figure 1(a-c)) or standard drugs, diclofenac and dexamethasone (Figure 2(a-b)) significantly reduced inflammation in the chicks and at a faster rate than saline group (control). In general, all plant extracts tested significantly reduced inflammation in a dose-dependent manner over time. When the total edema over the experimental period for all extracts was expressed as AUCs (in arbitrary units) over the time course curves, a dose-dependent effect in decreasing total edema was also observed (Figures 1(a-c); 2(a-b)). The dose of extract required to cause half-maximal reduction in edema (ED$_{50}$) for all extracts was determined. The most potent extract was that of Reissantia indica (ED$_{50}$ = 47.23 mg/kg) followed Grosseria vignei and Cissus cornifolia. Both Grosseria vignei and Cissus cornifolia had similar anti-inflammatory activities, with ED$_{50}$ values of 79.44 and 79.29 mg/kg, respectively (Table 4).

### 5. Discussion

When the presence of a foreign body in a host results in tissue injury or damage, the immune system of the host intervenes by initiating an acute inflammatory response. This initial response usually leads to minimal leukocyte accumulation and activation for the clearance of the foreign body. In instances where the acute inflammatory response is unable to eliminate the foreign body, the inflammatory process becomes persistent and develops new characteristics. This results in the development of a chronic inflammatory state. Pro-oxidative mechanisms involved in innate

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**Table 4. Reducing power, nitric oxide scavenging activity, hydrogen peroxide scavenging activity and anti-inflammatory activity of extracts of Reissantia indica, Cissus cornifolia and Grosseria vignei**

| Plant Extract or Standard Drug | Reducing Power IC$_{50}$ (µg/mL) | Nitric Oxide Scavenging IC$_{50}$ (µg/mL) | H$_2$O$_2$ Scavenged % | ED$_{50}$ ± SEM (mg/kg) |
|-------------------------------|----------------------------------|------------------------------------------|------------------------|------------------------|
| Reissantia indica             | 357.8 ± 0.68                     | 320.8 ± 3.2                              | 44.72 ± 0.06           | 47.23 ± 1.91           |
| Grosseria vignei              | 1637 ± 4.3                       | 1152 ± 8.7                               | 42.50 ± 0.57           | 79.29 ± 3.01           |
| Cissus cornifolia             | 5494 ± 9.7                       | 1381 ± 6.4                               | 14.33 ± 0.43           | 79.44 ± 2.86           |
| Ascorbic acid                 | 49.49 ± 1.04                     | 23.25 ± 0.6                              | 85.49 ± 0.31           | NA                     |
| BHT                           | 113.2 ± 2.36                     | NA                                        | NA                     | NA                     |
| Diclofenac                    | NA                               | NA                                        | 10.60 ± 0.72           | NA                     |
| Dexamethasone                 | NA                               | NA                                        | 0.61 ± 0.11            | NA                     |

Values are reported as mean ± SD of triplicate experiment; NA— not applicable.
immune clearance of triggers of inflammation often accumulate free radicals, reactive oxygen and nitrogen species which require antioxidants for their clearance. The link between inflammation and oxidative stress is well established and therefore require a multi-prong approach to alleviate the burden (Nathan, 2002, Allavena et al., 2008, Medzhitov, 2008). Natural products possessing both anti-inflammatory and antioxidant activities are therefore attractive in this regard. Various plant extracts reported to possess antioxidant activities do also possess anti-inflammatory activities (Ofori-Baah et al., 2019, Conforti et al., 2008, Ravipati et al., 2012). Several reports suggest that phytochemicals enhance longevity of cells, prevent aging and minimizes predisposition to certain inflammatory disorders (Arulselvan et al., 2016).

The plant species used in the study were selected based on their ethnomedicinal use in the treatment of infectious diseases, inflammation and stress-related diseases in Ghana. Ethanol was selected as extraction solvent to mimic the traditional mode of preparation of the plants. All
phytochemicals tested were present in extracts of *Reissantia indica* except for saponins. Alkaloids, flavonoids, terpenoids, triterpenoids, glycosides, coumarins and saponins were present in extracts of both *Cissus cornifolia* and *Grosseria vignei*. Previous studies on the butanol soluble fraction of the leaf of *Cissus cornifolia* revealed alkaloids, flavonoids and saponins (Yaro et al., 2015), similar to this study. Also, a gas chromatograph—mass spectrometry (GC-MS) analysis of the aqueous and ethanol extracts of the roots of *Cissus cornifolia* indicated the presence of the common aromatic phenolic compounds, pyrogallol, resorcinol and catechol as well as a fatty acid (n-hexadecanoic acid) and vanillin, which is an aldehyde (Chipiti et al., 2015). Studies elsewhere on the phytochemicals present in *Reissantia indica* correlated with the results of these studies, with alkaloids, flavonoids and some phenolic compounds present (Gayathri et al., 2018). Some steroids and terpenoids have even been isolated from the plant (Gamlat et al., 1988, Gamlat et al., 1989). Phytochemical data on *Grosseria vignei* are however absent in the literature and to the best of our knowledge, this is the first report of the phytoconstituents in ethanolic extracts of *Grosseria vignei*.

The total phenolic content (TPC) of *Reissantia indica* was greater than both *Cissus cornifolia* and *Grosseria vignei*. This may be due to the fact that both tannins and flavonoids were present in *Reissantia indica* but only one of those classes was present in *Cissus cornifolia* and *Grosseria vignei*. Since tannins are mainly a class of polyphenolic compounds (Chung et al., 1998), the absence of tannins could account for the low total phenolic content in the ethanol extract of *Cissus cornifolia*. Interestingly, there was a correlation between TPC and total antioxidant capacity (TAC). Extracts with high TPC also showed high TAC. This may be due to the fact that phenolic compounds are generally good antioxidants and so their presence in an extract could make that extract act as a potent antioxidant agent. Antioxidants are able to scavenge free radicals and reduce other oxidizing agents. In the nitric oxide scavenging assay, *Reissantia indica* extracts also showed great promise, with an IC$_{50}$ of 320.8 ± 3.2 µg/mL. Additionally, extracts of *Reissantia indica* proved superior to both *Cissus cornifolia* and *Grosseria vignei* in the reducing power and hydrogen peroxide scavenging assays. The superiority of *Reissantia indica* extract may be attributed to its high TPC. Inhibition of nitric oxide synthase or nitric oxide scavenging has been correlated to the anticancer potential of curcumin and curcuminoids (Rao, 1997). Scavenging of reactive oxygen species and the reduction of Fe (III) in methemoglobin to Fe (II) in hemoglobin prevent lipid peroxidation and oxidative stress that are hitherto implicated in the predisposition and progression of chronic inflammatory disorders (Çimen, 2008). *Reissantia indica* could be therefore explored in these respects as well.

Due to the fact that free radicals and reactive oxygen species are implicated in the inflammation cascade, the anti-inflammatory activities of the three plant extracts were also examined. All three extracts showed a dose-dependent reduction in edema, similar to the standard dexamethasone. The dose of extract required to cause half-maximal reduction in edema (ED$_{50}$) were 47.23, 79.44 and 79.29 mg/kg for *Reissantia indica*, *Cissus cornifolia* and *Grosseria vignei* respectively. There seemed to exist a direct correlation between antioxidant activity and anti-inflammatory activity as well. The ability of the extract to mop up reactive oxygen species, which could act as a trigger for inflammatory response, may be a very important factor in reducing inflammation. Ravipati and coworkers showed that plant extracts with high antioxidant activities do possess good anti-inflammatory activities (Ravipati et al., 2012). Also, *Mentha aquatica* L. (Lamiaceae), a Mediterranean herb with very high antioxidant activity was shown to be a good anti-inflammatory agent (Conforti et al., 2008). Recently, the ethanol extracts of *Strophantus gratus* and *Tamarindus indica* L. were shown to possess significant anti-inflammatory activity, with the concentration required to reduce carrageenan-induced edema in chicks determined to be greater than 100 mg/kg in both cases. All extracts tested in this work possessed better anti-inflammatory activity than the extracts of *Tamarindus indica* L. and *Strophantus gratus* (Ofori-Baah et al., 2019, Borquaye et al., 2020).
6. Conclusion

The ethanolic extracts of *Reissantia indica*, *Cissus cornifolia* and *Groseria vignei* have been shown to possess good anti-inflammatory and antioxidant activities. Of the three extracts tested, *Reissantia indica*, with tannins, flavonoids and alkaloids present, had the best anti-inflammatory and antioxidant activity. With the increasing need for alternatives to regulate the various forms of pro-oxidative and inflammatory processes, the use of herbal products with anti-inflammatory and antioxidant agents could be a viable option. The results of this study provide scientific backing for the use of *Reissantia indica*, *Cissus cornifolia* and *Groseria vignei* in such herbal preparations.

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Competing interests

The authors declare no competing financial, professional, or personal interests that might have influenced the performance or presentation of the work described in this manuscript.

Data Availability

All data generated or analyzed during this study are included in this published article.

Author contributions

LSB and MKL conceived the study. All experiments were designed by LSB, MKL and ENG. Plant materials were collected by MAB, PKB and AK. The experimental procedures were carried out by GD, MAB, PKB and AK under guidance from MKL and ENG. All authors were involved in data analyses. Initial manuscript was drafted by ENG and MKL and edited by LSB. All authors read and approved the final manuscript.

Ethics

The project proposal and procedures were reviewed and approved by the Institution Ethics Review Board for Animal Use at the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

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