Total phenolic and flavonoid contents, cytotoxic, immunomodulatory and anti-inflammatory potential of whole plant of *Astragalus creticus* (Fabaceae)

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Abstract

**Purpose:** To determine total phenolic and flavonoid contents, as well as the cytotoxic, immunomodulatory and anti-inflammatory potentials of the whole plant of *Astragalus creticus* (Fabaceae).

**Methods:** Folin-Ciocalteu (FC) method was used for determination of total phenolic and flavonoid contents of the methanol and dichloromethane extracts of *Astragalus creticus*. The cytotoxic potential of the extracts on 3T3 and HeLa cell lines were evaluated using MTT assay. Brine shrimp larvae mortality was determined by lethality bioassay, while inhibitory effects were determined on mouse fibroblast (3T3) and cervical cancer (HeLa) cell lines. In vitro immunomodulatory and in vivo anti-inflammatory effects were assessed using reactive oxygen species (ROS) chemiluminescence and formalin-induced rat paw edema assays, respectively.

**Results:** Dichloromethane extract had higher contents of phenolics (TPC = 324.75 ± 2.47 mg GAE/g) and flavonoids (TFC = 95.51 ± 0.82 QE/g) than the methanol extract (TPC = 79.82 ± 1.53 mg GAE/g, TFC = 56.11 ± 0.93 QE/g). The dichloromethane extract exhibited high cytotoxic and immunomodulatory potentials, with 76.66 % mortality in brine shrimp lethality bioassay and 83.9 % inhibition (IC₅₀ = 18.0 ± 1.1 µg/mL) in chemiluminescence assay. The extract also resulted in 22 and 13 % inhibition of viability of HeLa and 3T3 cells, respectively, while the methanol extract produced 13 % inhibition of both cell lines. The methanol extract produced very significant anti-inflammatory activity, with a maximum of 49 % inhibition of paw edema at a dose of 160 mg/kg (p < 0.01).

**Conclusion:** These results suggest that the dichloromethane and methanol extracts of *Astragalus creticus* (Fabaceae) exert cytotoxic, immunomodulatory and anti-inflammatory effects. These findings provide scientific validation for the traditional medicinal use of the *Astragalus* genus.

**Keywords:** *Astragalus creticus*, Brine shrimp lethality, Flavonoid, Cytotoxic, Immunomodulatory activity

INTRODUCTION

Fabaceae is popularly known as the pea, legume or bean family which comprises 751 genera and 19000 species [1]. *Astragalus creticus* is an important plant of the *Astragalus* genus which is well known in the field of herbal medicine. Plants of *Astragalus* genus are
traditionally used for treating various types of inflammation, healing of wounds, immunostimulation, and treatment of leukemia. Astragalus roots are used for preparation of popular herbal drugs in Traditional Chinese Medicine (TCM). These drugs exert hepatoprotective, immunostimulatory, anti-inflammatory, anti-perspiration, antidiabetic, antitumorogenic, and diuretic effects [2]. A list of traditionally-important Astragalus plants is presented in Table 1. Astragalus creticus is native to the mountainous areas of S. Balkans, Candia, Greece and many parts of Asia. In Pakistan, this species is predominantly found in tribal areas of Southern Punjab and Baluchistan such as Sakhi Sarwar and Fort Manro. The plant, which has the common name of Cretan Milk-vetch, is a rich source of high quality gum tragacanth [3].

The present study was designed as systematic and scientific investigations on the immune-modulatory, cytotoxic and anti-inflammatory potential of Astragalus creticus in order to validate its traditional and medicinal uses.

EXPERIMENTAL

Plant collection, identification, and preparation of extracts

The plant was collected near Fort Manro (tribal area of southern Punjab) in March, 2014. It was identified as Astragalus creticus by a taxonomist at Institute of Pure and Applied Biology, Bahauddin Zakariya University, Multan, and voucher no. (www.the plantlist.org/tpl1.1/record/ild.32000) was deposited at the herbarium of the institute. The whole plant of Astragalus creticus was shade-dried for 15 days, ground into coarse powder, and weighed. Then, 1000 g of the dried coarse powder was extracted using maceration in dichloromethane and methanol. The two extracts were concentrated using rotary evaporation under reduced pressure, and were labeled as ACWPD and ACWPM, for dichloromethane extract and methanol extract, respectively.

Determination of total phenolic content (TPC)

The test sample (100 μL) was mixed with 10 μL of 10 % diluted Folin-Ciocalteu reagent (FCR), and incubated for 10 min, followed by addition of 90 μL of 15 % (w/v) aqueous Na2CO3. The tube contents were pre-incubated at 37 ºC for 90 min, prior to measurement of absorbance at 750 nm. Gallic acid was used as positive control. Total phenolic contents (TPCs) were calculated from a gallic acid (GA) calibration curve, and expressed as mg of GA equivalents per gram of dry extract (mg GAE/g) [13]. Each assay was done in triplicate.

Determination of total flavonoid content (TFC)

A calibration curve was drawn using standard quercetin solution (1 mg/mL in methanol). The test sample (100 μL) was mixed with 25 μL of 1 % NaNO2 solution in a test tube, and allowed to stand for 5 min prior to addition of 10 μL of 10 % AlCl3 solution and 35 μL of 4 % NaOH.

<table>
<thead>
<tr>
<th>Plant name</th>
<th>Plant part used</th>
<th>Traditional uses</th>
<th>Preparation</th>
<th>Geographical zone(s)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. membranaceus</td>
<td>Roots</td>
<td>Anticancer and immunity enhancement</td>
<td>Decoction and tincture</td>
<td>China</td>
<td>[4]</td>
</tr>
<tr>
<td>A. pelecinus</td>
<td>Aerial parts</td>
<td>Healing of wounds</td>
<td>Aqueous extract</td>
<td>Palestine</td>
<td>[5]</td>
</tr>
<tr>
<td>A. chrysochlorus</td>
<td>Roots</td>
<td>Healing of wounds and treatment of leukemia.</td>
<td>Decoction</td>
<td>Anatolia (Turkey)</td>
<td>[6]</td>
</tr>
<tr>
<td></td>
<td>Pod</td>
<td>Inflammation of liver, ovaries, spleen and uterus</td>
<td>Paste</td>
<td>Afghanistan and Pakistan</td>
<td>[7]</td>
</tr>
<tr>
<td>A. hamosus</td>
<td>Fruits</td>
<td>Inflammation</td>
<td>Powder</td>
<td>Afghanistan and Pakistan</td>
<td>[8]</td>
</tr>
<tr>
<td>A. adsurgens</td>
<td>Aerial parts</td>
<td>Inflammation</td>
<td>Decoction</td>
<td>Iran</td>
<td>[9]</td>
</tr>
<tr>
<td>A. alopecias</td>
<td>Whole plant</td>
<td>Healing of wounds</td>
<td>Decoction</td>
<td>Russia and Tibet</td>
<td>[10]</td>
</tr>
<tr>
<td>A. trojanus</td>
<td>Roots</td>
<td>Leukemia</td>
<td>Aqueous extract</td>
<td>Russia and Tibet</td>
<td>[10]</td>
</tr>
<tr>
<td>A. taipaishanensis</td>
<td>Roots</td>
<td>Enhancement of immunity</td>
<td>Teas, infusions and decoction</td>
<td>Taibai mountains (China)</td>
<td>[12]</td>
</tr>
<tr>
<td>A. creticus</td>
<td></td>
<td>High quality gum tragacanth</td>
<td></td>
<td></td>
<td>[3]</td>
</tr>
</tbody>
</table>
Following dilution with 30 µL of methanol, the absorbance of the solution was read at 510nm. The flavonoid contents were calculated and expressed as milligram of quercetin equivalents per gram of dry extract (mg QE/g DE) [13].

**Brine-shrimp lethality bioassay**

Artificial sea water was prepared by dissolving 3.8 g of sodium chloride (sea salt) in 1000 mL of H₂O, followed by filtration. Then, shrimp eggs were added to the water. When the eggs were hatched, the shrimp larvae were allowed to mature at 22-29 °C in 2 days. Then, graded concentrations of each extract (10, 100, 1000 µg/mL) were added in triplicate into different vials. Plant extract (20 mg) was dissolved in 2 mL of solvent, and the sample was transferred to vials to generate concentrations of 10, 100, 1000 µg/mL, respectively. Etoposide was used as standard drug. To each vial, 10 shrimps and 5 mL sea water (30 shrimps/dilution) were added, followed by exposure to illuminating light for 24 h. Shrimps that survived were counted and used for Probit analysis (Finney Computer program) [14].

**Cytotoxicity assay**

Cell viability was determined by checking the ability of the cells to oxidize 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyl tetrazolium bromide (MTT reagent) and generate formazan crystals. The 3T3 and HeLa cells were cultured in Dulbecco’s modified eagle medium (DMEM) and minimum essential medium eagle (MEME), respectively. The culture media were supplemented with penicillin (100 units/mL), 5 % FBS, and streptomycin (100 µg/mL) in a 75-cm² culture flask, and placed in a 5 % carbon dioxide incubator at 37 °C. The cells were counted with a hemocytometer, and diluted in appropriate specific medium. Each cell was cultured at a density of 5 x 10⁴ cells/mL in 96-well plates at a volume of 100 µL per well. After overnight incubation, the medium in each well was replaced with 200 µL fresh medium containing a different concentration of sample extract, with extract concentrations ranging from 1 to 30 µM. Then, the wells were incubated for 48 h, after which 200 µL MTT (0.5 mg/mL) was added to each well, followed by further incubation for 4 h. Thereafter, the medium in each well was discarded and replaced with 100 µL of DMSO, in order to solubilize the resultant formazan crystals. The absorbance of the formazan solution in each well was measured at 540 nm in a Spectra Max plus microplate reader, and the inhibition of cell viability (H) was calculated as shown in Eq 1. H (%) = \{100 - (As - An)/(Ac - An)\} x 100 where As, An and Ac are the absorbance of sample, negative and positive control samples, respectively.

Soft-Max Proof software (US) was used for calculation [15].

**Evaluation of immunomodulatory effect**

Diluted whole blood (1:5 in sterile PBS, pH 7.4, 25 µL) and PMNs (1×10⁶) suspended in HBSS++ were incubated with 25 µL of various concentrations of each extract (1, 10 and 100 µg/mL) in triplicate in 96-well plates. The control wells contained only cells and HBSS++. Then 96-well plates were incubated at 37 °C for 15 min in a luminometer thermostat chamber. Theretofore, 25 µL of SOZ and 25 µL of ROS probe were introduced to each well. The ROS levels were determined in the luminometer in terms of RLU [16].

**Determination of anti-inflammatory activity**

White albino mice weighing 25-30 g were kept safely in steel cages and provided free access to standard chow feed and water in a well-ventilated room at 25±2 °C at 12-h light/12-h dark cycle. The animal experiments were carried out in strict compliance with the policies and protocols recommended by Institutional Animal Ethical Committee of Faculty of Pharmacy, Bahauddin Zakriya University, Multan. The committee also granted approval for the various experiments (approval ref no. 13/PEC/2019). International guidelines for animal studies were followed.

**Establishment of formalin-induced rat paw edema**

Albino mice were randomly assigned to 4 groups (n = 5). Group 1 mice received normal saline only, at a dose of 0.1mL/kg. Group 2 was treated intraperitoneally with indomethacin at a dose of 10 mg/kg, while ACWPM was administered to the 3rd and 4th experimental groups at doses 80 and 160mg/kg, respectively. Subcutaneous formalin injection (10 % w/v; 0.5 mL) was administered to groups 2, 3 and 4 after 30 min of their respective treatments as indicated above. Then, at 0, 1, 2 and 3 h after the administration of formalin, paw size was measured by wrapping a cotton thread around each rat paw and measuring the length of the thread using a metric ruler [17].
Statistical analysis

All results are expressed as mean ± SEM (n = 5). Student’s t-test was used for statistical analysis of differences between two groups, while one-way analysis of variance (ANOVA) and Dunnet’s test for multiple comparisons were used to analyze differences in anti-inflammatory data among groups. All statistical analyses were done with SPSS version 24 software. Statistical significance of difference was assumed at p < 0.05.

RESULTS

Total phenolic (TPC) and total flavonoid contents (TFC)

Total phenolic and flavonoid contents were calculated in dichloromethane and methanol extracts of whole plant of *Astragalus creticus*. The results illustrate that dichloromethane extract (ACWPD) contained higher phenolic; 324.75 ± 2.47 and flavonoid; 95.51 ± 0.82 contents as compared to methanol extract (ACWPM) of *Astragalus creticus*. The flavonoid/phenolic ratio (F/P) of ACWPD and ACWPM extracts was indicated at 0.29 and 0.70, respectively (Table 2).

Table 2: TPC and TFC of the two *Astragalus creticus* extracts

<table>
<thead>
<tr>
<th>Extract</th>
<th>TPC (mg GAE/g of DE)</th>
<th>TFC (mg QE/g of DE)</th>
<th>Flavonoid: phenolic (F:P) ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACWPD</td>
<td>324.75±2.47</td>
<td>95.51±0.82</td>
<td>0.29</td>
</tr>
<tr>
<td>ACWPM</td>
<td>79.82±1.53</td>
<td>56.11±0.93</td>
<td>0.70</td>
</tr>
</tbody>
</table>

Values are expressed as mean ± SEM

Cytotoxic activity

*Brine-shrimp lethality bioassay*

The results showed that ACWPD produced better cytotoxic effect, with 6.66, 10 and 76.66 % mortality values, than ACWPM which produced mortality values of 10, 16.66 and 20.00 % against brine shrimp larvae at concentrations of 10, 100 and 1000 µg/mL, respectively. The standard drug (etoposide) resulted in 46.66 % mortality at a concentration of 7.46 µg/mL (Table 3).

Table 3: Cytotoxic effect of *Astragalus creticus* extracts in brine shrimp lethality assay

<table>
<thead>
<tr>
<th>Extract</th>
<th>Concentration (µg/ml)</th>
<th>No. of shrimps taken</th>
<th>No. of shrimps that survived</th>
<th>Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACWPD</td>
<td>10</td>
<td>30</td>
<td>28</td>
<td>66.7</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>30</td>
<td>27</td>
<td>10.0</td>
</tr>
<tr>
<td></td>
<td>1000</td>
<td>30</td>
<td>07</td>
<td>76.7</td>
</tr>
<tr>
<td>ACWPM</td>
<td>10</td>
<td>30</td>
<td>27</td>
<td>10.0</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>30</td>
<td>25</td>
<td>16.7</td>
</tr>
<tr>
<td></td>
<td>1000</td>
<td>30</td>
<td>24</td>
<td>20.0</td>
</tr>
<tr>
<td>Etoposide (standard drug)</td>
<td>7.46</td>
<td>30</td>
<td>16</td>
<td>46.7</td>
</tr>
</tbody>
</table>

Cytotoxicity against 3T3 cell line

Results from MTT assay on 3T3 cells revealed that ACWPD and ACWPM produced 13 % inhibition, relative to the standard drug (cycloheximide) which produced 70 % inhibition at IC$_{50}$ of 0.8 ± 0.2 µg/mL (Table 4).

Cytotoxicity against HeLa cell line

The anticaner effects of the extracts were further tested against HeLa cell lines using MTT assay. Both samples (ACWPD and ACWPM) produced moderate inhibitory effects: 22 and 13 % respectively, relative to the standard drug cycloheximide which produced 70 % Inhibition at IC$_{50}$ value of 1.2 ± 0.2µg/mL (Table 4).

Immunomodulatory effect

The immunomodulatory effects of ACWPD and ACWPM were determined using oxidative burst assay. The results showed that ACWPD exhibited high level of immunomodulatory effect, with 83.9 % inhibition, and IC$_{50}$ value of 18.0±1.1µg/mL. In contrast, ACWPM exerted

Table 4: Cytotoxic effect of *Astragalus creticus* extracts against HeLa and 3T3 cell lines assay

<table>
<thead>
<tr>
<th>Extract</th>
<th>Concentration (µg/mL)</th>
<th>HeLa cell line (%)</th>
<th>3T3 cell line (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACWPD</td>
<td>30</td>
<td>22</td>
<td>13</td>
</tr>
<tr>
<td>ACWPM</td>
<td>30</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Cycloheximide (standard drug)</td>
<td>30</td>
<td>70</td>
<td>70</td>
</tr>
</tbody>
</table>
Table 5: Immunomodulatory effect of Astragalus creticus extracts

<table>
<thead>
<tr>
<th>Extract</th>
<th>Concentration (µg/mL)</th>
<th>Inhibition (%)</th>
<th>IC50 (µg/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACWPD</td>
<td>25</td>
<td>83.9</td>
<td>18.0±1.1</td>
</tr>
<tr>
<td>ACWPM</td>
<td>25</td>
<td>38.6</td>
<td></td>
</tr>
<tr>
<td>Ibuprofen (standard drug)</td>
<td>25</td>
<td>73.2</td>
<td>11.2±1.9</td>
</tr>
</tbody>
</table>

Table 6: Anti-inflammatory effects of Astragalus creticus extracts

<table>
<thead>
<tr>
<th>Group</th>
<th>Dose (mg/kg)</th>
<th>Normal</th>
<th>1 h</th>
<th>2 h</th>
<th>3 h</th>
<th>1 h</th>
<th>2 h</th>
<th>3 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>-</td>
<td>1.04±0.17</td>
<td>3.33±0.75</td>
<td>4.45±0.31</td>
<td>5.07±0.28</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Indomethacin</td>
<td>10</td>
<td>0.99±0.08</td>
<td>1.63±0.42**</td>
<td>1.83±0.14**</td>
<td>1.97±0.12**</td>
<td>51%</td>
<td>59%</td>
<td>61%</td>
</tr>
<tr>
<td>ACWPM</td>
<td>80</td>
<td>0.96±0.13</td>
<td>2.43±0.46*</td>
<td>2.45±0.13**</td>
<td>2.74±0.13**</td>
<td>26%</td>
<td>46%</td>
<td>45%</td>
</tr>
<tr>
<td>ACWPM</td>
<td>160</td>
<td>1.01±0.05</td>
<td>2.43±0.52</td>
<td>2.43±0.21*</td>
<td>2.56±0.17**</td>
<td>27%</td>
<td>46%</td>
<td>49%</td>
</tr>
</tbody>
</table>

Values shown are mean ± SEM (n = 5). *P < 0.05; **p < 0.01

moderate activity, with 38.6 % inhibition, when compared with Ibuprofen (73.2 % inhibition, with IC50 of 11.2±1.9µg/mL, Table 5).

Anti-inflammatory activity

The values of % inhibition of inflammation for ACWPM and indomethacin (standard drug) were determined at various time intervals i.e., 1, 2 and 3 h. The results showed that ACWPM exerted significant anti-inflammatory potential when tested at concentrations of 80 and 160 mg/kg. The extract ACWPM produced a maximum of 46 % inhibition at a dose of 80 mg/kg after 2 h. At a dose of 160 mg/kg, ACWPM administration resulted in 49 % inhibition of paw edema after 3 h. The changes in mean paw edema and the corresponding % inhibitions are presented in Table 6.

DISCUSSION

Phenolics are widely distributed in the plant kingdom. Studies have shown that phenolic compounds are beneficial for the prevention and treatment of bacterial and viral infections, as well as cancer and inflammatory diseases [18]. Thus, the quantification of phenolic compounds in plants is of paramount medicinal importance. Cancer is a malignant disease associated with millions of deaths worldwide. In 2015 alone, there were at least 17.5 million new cancer cases, and 8.7 million deaths worldwide [19]. In spite of all improvements in cancer therapy, survival from cancer is still low, and many cancer patients suffer from relapse as well as adverse effects of anti-cancer drugs. Moreover, the development of resistance to existing chemotherapeutic agents is a vital problem in cancer treatment. Therefore, there is need to evolve novel chemotherapeutic strategies for cancer [20].

The brine-shrimp lethality bioassay gives frontline cytotoxicity information which can be backed up with more sophisticated and specific bioassays. It has been reported that the brine shrimp lethality bioassay has a good correlation with the cytotoxicity of plant bioactive substances against some human solid tumors [14]. Indeed, several natural pesticidal and antitumor agents have been identified through screening using this assay. The 3T3 cells are mouse embryo fibroblasts colonial cells which are responsible for oncogenic activity of spontaneous human tumor-transfected DNA. Despite their limited susceptibility to transformation after transfection with DNA from neoplastic tissue, 3T3 cells play a vital role in the development of the molecular genetics of cellular oncogenes [21].

It has been revealed that the anticancer activities of plant extracts on HeLa cells are due to induction of apoptosis via the intrinsic and extrinsic pathways. This hypothesis is supported by previous studies which demonstrated the antiproliferative effects of extracts of Emilia sonchifolia, Solanum lyratum, Vatica diospyroides, Cotinus coggygri, Rosa damascene, Colchicum sanguicolle and Centaurea antiochia [22]. The choice of HeLa cells is based on the fact that cervical cancer is the fourth most widely diagnosed cancer in women worldwide. Thus, new therapies are required for cervical cancer.

Reactive oxygen species (ROS) are generated via oxidative burst which has been implicated as the key underlying mechanism of tumoricidal and antimicrobial effects. Oxidative stress is closely linked to carcinogenesis because ROS function in various epigenetic factors involved in the induction, promotion, and modulation of cervical and breast cancers [24]. Recent findings indicate
improved outcomes in the use of immunomodulatory drugs for treatment of cancer patients. Thus, ongoing investigations on the use of various treatment combinations for enhancing immunity against cancer are of prime importance in combating this disease [25].

Formalin-induced paw edema is a widely used experimental model for studying acute inflammatory response. Plant extracts that show anti-inflammatory potential are likely to inhibit the release of inflammatory mediators, and suppress accumulation of macrophages and neutrophils within 1-5 h following both phases of edema [26]. In this study, the results obtained with Astragalus creticus are consistent with the folkloric uses and experimentally-tested anti-inflammatory potential of various Astragalus species such as A. fasciculifolius, A. membranaceus, A. sinicus, A. gummifer, and A. hamosus [27]. Phenolic compounds derived from ginger (gingerol and 6-shogaol) exhibit significant anticancer potential against breast, brain and lung cancers. The present study showed that Astragalus creticus extracts were rich in phenolic and flavonoid contents which were responsible for the observed cytotoxic effects against against brine shrimp lethality bioassay, 3T3 and HeLa cell lines [28].

CONCLUSION

The results of the present study demonstrate the potential cytotoxic, immunomodulatory and anti-inflammatory activities of Astragalus creticus. Phenolics and flavonoids, being the major phytoconstituents, may be responsible for these activities. Further research is required, using other models, to elucidate the possible mechanism of action and to identify bioactive components that are responsible for the observed activities.

DECLARATIONS

Acknowledgement

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Conflict of interest

No conflict of interest is associated with this study.

Contribution of authors

We declare that this work was done by the authors named in this article, and all liabilities pertaining to claims relating to the content of this article will be borne by the authors.

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