Introduction

It is known that complement system plays an important role in the host defense system, inflammations and allergic reactions. A considerable number of Chinese herbs have been found to be anti-inflammatory (1). These findings present the possibility that these herbs may contain some kinds of regulators of the complement system. Recently, we have found potent anti-complementary activities in the extracts of some Chinese herbs (2), such as in the extract of the leaves of Artemisia princeps Pamp. Artemisiae Argyi Folium, the leaves of A. princeps Pamp (Japanese name = Gaiyo), is a well known crude drug clinically used in the treatment of colic pain, vomiting and diarrhea, and irregular bleeding from uterus. The hairs on the undersurface of the leaves of A. princeps have also been used as moxa for moxibustion. Previously, we reported that the hot-water extract of moxa contained potent anti-complementary activity, and the activity was observed in the non-dialyzable carbohydrate of moxa contained potent anti-complementary activity, respectively. AAF-IIb-2 and IIb-3 were shown to have more potent activity than AAF-IIb-3. Anti-complementary activity of AAF-IIb-3 was almost similar with that of crude AR-arabinogalactan from the root of Angelica acutiloba Kitagawa, but AAF-IIb-2 and IIb-3 showed more potent activity than anti-complementary β-glucan, lentinan.

The present paper describes the purification and chemical characterization of the major anti-complementary polysaccharides from the leaves of A. princeps (Pamp) which is the raw material of moxa.
against H₂O for 2 days. The non-dialyzable solution was concentrated to about 20 ml, and 20 mg of NaBH₄ was added to the concentrate while being continuously stirred for 12 h at room temperature. After the neutralization of the reaction mixture with AcOH, the H₃BO₃ in the sample was removed by the repeated addition and evaporation of MeOH. Finally, the oxidised AAF-IIb was obtained as the lyophilisate after the dialysis.

**Anti-complementary activity**

The anti-complementary activity was measured according to the previously described procedure (12) except distilled water (DIW) was used for dilutions instead of phosphate buffered saline, PBS (pH 7.4).

**Materials**

The leaves of *Artemisia princeps* Pamp (Japanese name = Gaiyō) and the seed of *Ricinus communis* were purchased from Uchida Wakanyaku Co. Ltd., Tokyo, Japan. Concanavalin-A (Con-A) Sepharose, CNBr-activated Sepharose 4B, Sephadex G-100 and Sepharose CL-4B and CL-2B were obtained from Pharmacia Co. Ltd. Pronase was purchased from Kaken-kagaku Co. Ltd. (Tokyo). *Ricinus communis* agglutinin (RCA) was purified from the extract of *R. communis* by the method of Adair and Kornfeld (13). RCA-Sepharose was prepared by the coupling of RCA and CNBr-activated Sepharose (14). Lentinan from *Lentinus edodes* was a gift from Dr. G. Chihara.

**Results**

**Fractionation of polysaccharides from Artemisia princeps Pamp**

The crude polysaccharide fraction was prepared after the reflux of the lyophilized extract with MeOH. The crude polysaccharide fraction showed potent anti-complementary activity dose dependently but the MeOH-soluble fraction did not show the activity even when concentrated materials were used for the assay. The crude polysaccharide fraction was further separated on the column of DEAE-Sepharose (Cl⁻) into unabsorbed fractions (AAF-Ia, b) and absorbed fractions (AAF-IIa, b, c) by the elution with a linear gradient of NaCl (Fig. 1). Furthermore, the remaining absorbed fraction (AAF-IIId) was obtained by the elution with 2 M NaCl (data not shown). Fig. 2 shows the anti-complementary activity after the incubation of the different concentrations of the polysaccharide fractions with NHS. The anti-complementary activities are shown to be dose dependent. When 1000 µg/ml of IIa was incubated with an equal volume of NHS about 90% of the TCH₅₀ was reduced. The order of the activities of these fractions was IIa > IIb > Ia > Ic > IIId > Ib. The chemical properties of these subfractions are summarized in Table I. The most active fraction, IIa, contained arabinose, galactose, mannose, glucose and uronic acid. The major polysaccharide fraction, IIb, contained arabinose, galactose, and xylose as the major neutral sugar, and a large amount of uronic acid which was estimated to be galacturonic acid by TLC of the acid hydrolysates.

**Table I. Chemical Properties of Polysaccharide Fraction from A. Princeps**

<table>
<thead>
<tr>
<th>(%)</th>
<th>Ia</th>
<th>Ib</th>
<th>IIa</th>
<th>IIb</th>
<th>IIc</th>
<th>IIId</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total hexose</td>
<td>45.8</td>
<td>44.6</td>
<td>117.3*</td>
<td>70.5</td>
<td>38.5</td>
<td>34.3</td>
</tr>
<tr>
<td>Total uronic acid</td>
<td>0.4</td>
<td>0.8</td>
<td>11.0</td>
<td>71.6</td>
<td>4.5</td>
<td>8.8</td>
</tr>
<tr>
<td>Total protein</td>
<td>&lt; 1.0</td>
<td>6.2</td>
<td>6.2</td>
<td>8.6</td>
<td>31.7</td>
<td>79.5</td>
</tr>
<tr>
<td>(Component sugars)</td>
<td>(Molar ratios)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arabinose</td>
<td>54.1</td>
<td>30.5</td>
<td>38.8</td>
<td>36.4</td>
<td>78.0</td>
<td>30.7</td>
</tr>
<tr>
<td>Xylose</td>
<td>2.3</td>
<td>2.5</td>
<td>3.9</td>
<td>14.8</td>
<td>1.7</td>
<td>2.5</td>
</tr>
<tr>
<td>Mannose</td>
<td>12.5</td>
<td>19.5</td>
<td>16.2</td>
<td>6.5</td>
<td>3.2</td>
<td>4.1</td>
</tr>
<tr>
<td>Galactose</td>
<td>11.9</td>
<td>14.4</td>
<td>26.5</td>
<td>29.3</td>
<td>11.3</td>
<td>30.1</td>
</tr>
<tr>
<td>Glucose</td>
<td>5.7</td>
<td>33.2</td>
<td>13.8</td>
<td>4.9</td>
<td>5.7</td>
<td>25.3</td>
</tr>
</tbody>
</table>

* High value was given by phenol-sulfuric acid assay using arabinose as the standard because hexose is more sensitive than arabinose in this assay.
This fraction was used for further purification. The anti-complementary activity of the deproteinized IIb did not change significantly, compared with that of IIb, but its activity was found to decrease with the periodate oxidation of IIb (Fig. 3). The yield of AAF-IIb was 25.5% from the crude polysaccharide fraction.

Purification of the anti-complementary polysaccharide, AAF-IIb

AAF-IIb was found to contain a remarkable amount of galactose and was further purified by affinity chromatography on RCA-Sepharose. The RCA unbound fractions showed higher activity than the bound fraction (data not shown). The RCA unbound fraction (yield; 92.5% from AAF-IIb) was further fractionated by Con-A Sepharose because the RCA-unbound fraction was found to contain mannose. However the amount of the Con-A bound fraction obtained by this second affinity chromatography was insignificant. The RCA-unbound fraction (yield; 13% from RCA-unbound fraction) yielded galactose, xylose, rhamnose, arabinose, galacturoninic acid and a trace of mannose on hydrolysis whereas the fraction of smallest molecular weight contained a large amount of galac-
Table II. Properties of Anti-complementary Polysaccharides from A. princeps

<table>
<thead>
<tr>
<th>Component sugars</th>
<th>AAF-IIb-2</th>
<th>AAF-IIb-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rhamnose</td>
<td>2.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Xylose</td>
<td>2.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Arabinose</td>
<td>4.3</td>
<td>9.4</td>
</tr>
<tr>
<td>Galactose</td>
<td>3.6</td>
<td>7.5</td>
</tr>
<tr>
<td>Glucose</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Fig. 7. Anti-complementary activity of purified anti-complementary polysaccharides, AAF-IIb-1, 2 and 3, from Fig. 6 on Sepharose CL-4B. ▲ AAF-IIb-1; ● AAF-IIb-2; ○ AAF-IIb-3; □ lentinan; ■ crude AR-arabinogalactan from A. acutiloba Kitagawa.

Properties of anti-complementary polysaccharides, AAF-IIb-2 and AAF-IIb-3

The molecular weights of AAF-IIb-2 and IIb-3 were estimated to be 139,000 and 31,000 by the calibration of gel filtration on Sepharose CL-4B (0.2 M NaCl). AAF-IIb-3 contained a more substantial amount of hexose than AAF-IIb-2, while AAF-IIb-2 contained a more substantial amount of uronic acid than AAF-IIb-3 (Table II). AAF-IIb-2 was composed of arabinose, galactose, rhamnose, xylose and a small amount of glucose while AAF-IIb-3 was composed of arabinose, galactose and small amounts of rhamnose, xylose and glucose. The anti-complementary activity of AAF-IIb-3 was almost similar with that of crude arabinogalactan from the root of Angelica acutiloba Kitagawa, but AAF-IIb-2 and IIb-3 showed more potent activity than anti-complementary glucan, lentinan (Fig. 7).

Discussion

It has been reported that the several immunomodulating activities were found in the crude polysaccharide fractions of the higher plants (15–17), however further purification of the active polysaccharide was not carried out in these studies. The extract of the leaves of A. princeps Pamp was found to contain potent anti-complementary activity, and major anti-complementary polysaccharides from A. princeps Pamp have now been purified and are characterized in the present paper. Anti-complementary activity was shown to be present in the crude polysaccharide fraction but not in other fractions. The activity was observed in the neutral and acidic polysaccharide fractions. The acidic major polysaccharide fraction, AAF-IIb, showed potent activity which was significantly reduced after periodate oxidation but not after Pronase treatment. These results indicate that the carbohydrate moiety contributes to the activity. The major anti-complementary polysaccharides from AAF-IIb did not have affinities to RCA and Con-A. This suggests that the significant amounts of galactosyl and glucosyl residues are not present at the non-reducing ends. The anti-complementary polysaccharide from AAF-IIb showed a broad single peak by gel filtration on Sepharose CL-4B, but AAF-IIb contained at least three kinds of anti-complementary polysaccharides which have a different molecular weight. The present results indicate that the major anti-complementary polysaccharides, AAF-IIb-2 and IIb-3, are probably structurally related polymers because both polysaccharides were composed of the same component sugars, but their molar ratios differed from each other. Both polysaccharides contained remarkable amounts of arabinose and galactose, and their molar ratios were almost same value (1.2:1.0). It was suggested that AAF-IIb-2 and IIb-3 may contain similar arabinogalactan moiety. In a previous study it was shown by this research group that an anti-complementary arabinogalactan was isolated from the root of A. acutiloba Kitagawa (AR-arabinogalactan IIa) (12, 18). Crude AR-arabinogalactan IIa showed almost similar activity with AAF-IIb-3. It was expected that arabinogalactan moiety may participate in the anti-complementary activity.

Some anti-complementary polysaccharides have already been isolated from bacteria, fungi and plants, but not yet from Chinese crude drugs except β-1,3-glucan from Poria cocos (19), Lentinus edodes (19) and Coriolus versicolor (20) or AR-arabinogalactan IIa from A. acutiloba Kitagawa (12, 18). Major anti-complementary polysaccharides from A. princeps Pamp showed more potent activity than anti-complementary β-1,3-glucan from L. edodes. AAF-IIb-2 and IIb-3 contained remarkable amounts of galacturonic acid. But uronic acid containing anti-complementary polysaccharide has not yet been reported. Another acidic polysaccharide, pectin from apple or A. acutiloba did not show the significant anti-complementary activity in comparison with AAF-IIb-2 and IIb-3 (unpublished). These facts indicate that the anti-complementary acidic heteroglycan from A. princeps Pamp plays important role in the effect of Chinese crude drugs, and is also useful for the study of complement system.
Further studies of the structural analysis and mode of anti-complementary activity of this unique acidic heteroglycan are now in progress.

Acknowledgements

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References


Activation of Anthranilic Acid and N-Methylanthranilic Acid by Cell-free Extracts from Ruta graveolens Tissue Cultures

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Abstract: Cell-free extracts of Ruta graveolens tissue cultures obtained after (NH4)2SO4 precipitation and gel filtration on Sephadex G-25 catalyze the ATP-dependent activation of N-methylanthranilic acid according to the hydroxamate method. The rate of the enzyme reaction was shown to be linear for about 75 min and was proportional to the protein concentration up to at least 0.75 mg/ml of the enzyme preparation. This particular enzyme activity was only detectable in acridone alkaloid producing tissue cultures. Apparently activation of N-methylanthranilic acid is the second pathway-specific step in acridone alkaloid biosynthesis. It is not yet clarified if the activation takes place via the corresponding acyl adenylate or via phosphorylation.

Introduction

A number of protein amino acids and some other closely related compounds i.e. ornithine, nicotinic acid and anthranilic acid are essential precursors in alkaloid biosynthesis. Usually amino acids are decarboxylated during the course of the formation of various nitrogen-containing heterocyclic ring systems. In this context anthranilic acid occupies an unique position. In anthranilate-derived alkaloids, the carboxyl group is retained and takes part in the biosynthesis of the different heterocycles. To this particular group of secondary metabolites belong the acridone alkaloids which are exclusively found in some genera of the Rutaceae. It was argued for thermodynamical reasons that “activated” anthranilic acid might react with malonyl-CoA in the course of acridone biosynthesis (1). Anthraniloyl-coenzyme A (CoA) thioester seemed to be the most likely candidate. It is now well established that the N-methylation of anthranilic acid catalyzed by a particular N-methyltransferase is the first pathway-specific step in acridone biosyn-