Composition of Alginates from Brown Seaweeds, Sargassum and Padina spp.

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ABSTRACT

The percentage yield of alginate in brown seaweeds, Sargassum and Padina spp., from Sabah, and the intrinsic viscosities of these alginates were determined. Young and mature Sargassum, respectively, gave 35% and 32%, while Padina only yielded 18.5% of alginate. The intrinsic viscosities $[\eta]$ obtained were 412 mL/g and 312 mL/g for alginates from mature Sargassum and Padina, respectively. It was found that these intrinsic viscosities depend on the source and species of seaweeds. Treating the alginate sample with bleaching agent such as NaOCl yielded samples with $[\eta] = 210$ mL/g. However, a higher intrinsic viscosity, $[\eta] = 650$ mL/g, was obtained from Sargassum samples which were pre-treated in dilute formaldehyde solution. Results from intrinsic viscosity determination were used to estimate the viscosity average molecular weight, $M_v$, of the phycocolloid using the Mark-Houwink equation. Block compositions of alginates were determined using the technique of partial heterogenous hydrolysis. Results showed that young Sargassum was richer in the poly (β-D-mannuronate) block, while matured Sargassum was richer in the poly (α-L-guluronate) block. From these compositions, $M/G$ ratios were estimated as

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1.27, 0.64 and 0.85 for alginates from young Sargassum, mature Sargassum and Padina, respectively. This shows that mature Sargassum yields alginates with the lowest M/G ratio.

INTRODUCTION
Alginate is the major structural polysaccharide found in brown seaweeds (Phaeophyceae), which represent the commercial source from which alginates are extracted for use as gelling agents and stabilizers in food and other industries (Overeem, 1979; Whistler, 1973). However, certain species of bacteria, such as Azotobacter vinelandii and Pseudomonas aeruginosa, were also reported to produce alginates (Larsen and Haug, 1971).

Chemically, alginate is a (1→4) linked, linear copolymer of α-L-guluronate and β-D-mannuronate arranged in block structures (Haug and Larsen, 1962; Penman and Sanderson, 1972). The structures consist of homopolymeric buckled ribbons of poly (α-L-guluronate) which play an important role in the calcium ion mediated gelation mechanism (Morris et al., 1978), and poly (β-D-mannuronate), together with sequence that approximate to alternating guluronate-mannuronate repeating units (Haug et al., 1967; Boyd and Turvey, 1978), which are not involved in gelation.

The relative portions of these residues and their sequences within the primary structure vary from species to species (Haug et al., 1974; Strockton et al., 1980). Gel properties depend on these block structures and the poly (β-D-mannuronate)/poly (α-L-guluronate) or M/G ratio. The lower the M/G ratio, the stronger and more brittle is the gel that is formed (Penman and Sanderson, 1972). Gelation occurs through the formation of “egg-box” structures by the poly (α-L-guluronate) blocks which strongly chelate Ca$^{2+}$ (Morris et al., 1978).

In view of the fact that different species of brown seaweeds produce alginates of different compositions and structures (Haug et al., 1974), it is important to characterise alginate from a new source of seaweeds, in order to evaluate its commercial potential as stabilizers and gelling agents. In this study we investigated the uronic acid compositions and viscosity of alginates isolated from Sargassum spp. and Padina spp. from Sabah, Malaysia. Sargassum is the major species of brown seaweeds found growing along the rocky coast of Sabah, while Padina appears to be the second most important brown seaweed in term of abundance.

Alginate were extracted from these seaweed samples by the modified method of Haug (1959), using 1% (w/v) Na$_2$CO$_3$ solution. In an earlier study we reported that alginate extracted from Sargassum, which was pre-soaked overnight in dilute HCl(0.1 M) prior to extraction in 1% Na$_2$CO$_3$, was shown to possess low intrinsic viscosity (Omar and Ghani, 1986).

In the present study, we investigated the effect of adding bleaching agent, sodium hypochlorite (NaOCl), to alginate extract and the viscosity property of alginate solution was investigated. Bleaching agents such as NaOCl and Ca(OCl)$_2$ are often employed in industrial preparation of alginates (Chapman and Chapman, 1980). Seaweed samples were also treated by soaking overnight in dilute aqueous formaldehyde solution, prior to extraction in 1% Na$_2$CO$_3$ solution, in order to remove phenolic compounds. The effect of such a treatment on alginate viscosity property was studied. The M/G ratios for alginates isolated from young and mature Sargassum spp. and from Padina spp. were compared.

MATERIALS AND METHODS
Collection of Seaweeds and Extraction of Alginates
Seaweeds samples were collected from Kuala Abai, near Kota Belud, Sabah (Malaysia), in November 1985. Samples were washed thoroughly with tap and distilled water, sun dried and ground to powder form. About 10 g of the dry sample was extracted for alginate in 250 mL. 1% (w/v) Na$_2$CO$_3$ for 24 hours at room temperature. Another 10 g of dry ground seaweed sample was similarly extracted in 3% (w/v) Na$_2$CO$_3$ solution. From each extract, a viscous brownish solution was obtained, and this was filtered on muslin cloth. Alginate was precipitated as the sodium salt by addition of approximately 3 volumes of ethanol to the aqueous solution. This was filtered by vacuum suction and washed twice with ethanol and once with diethyl ether, Sodium alginate obtained was yellowish in colour, and dried in the oven at 35–40°C and its yield determined.
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A 10 g of dry Sargassum sample was soaked in 30% (w/v) aqueous formaldehyde solution for 12 hours in order to remove phenolic compounds. The solvent was filtered off and the seaweed washed with distilled water, then allowed to dry in the sun. Sodium alginate was then extracted using 1% Na\textsubscript{2}CO\textsubscript{3} according to the procedure described earlier.

**Bleaching of Sodium Alginate Product**

Seaweed extract from *Sargassum* spp. was bleached with sodium hypochlorite solution until the viscous brownish solution of sodium alginate turned to pale brown. The discoloured product was then precipitated in ethanol and treated as before.

**Moisture Content**

About 1 g sodium alginate prepared above was accurately weighed and dried in a vacuum oven at 70 °C for 24 hours. The sample was allowed to cool to room temperature in a vacuum desiccator and re-weighed. Moisture content of the alginate sample was determined from the weight difference and expressed as percentage of original weight.

**Block Composition and M/G Ratio**

Block composition of sodium alginates was determined by partial heterogenous hydrolysis (Haug et al., 1974). About 1 g sample was accurately weighed and hydrolysed in 100 mL 0.3 M HCl for 2 hours at 100 °C. A suspension was formed, allowed to cool to room temperature, and centrifuged at 4000 rev/min. for 2 hours. The supernatant, referred to as fraction A, was decanted off and the amount of alginate in the soluble fraction was measured by phenol-sulphuric acid reaction (Dubois et al., 1956), using moisture known commercial samples as standard.

The residue from above was re-dissolved in a small amount of 0.1 M NaOH solution and then diluted to 50 mL by adding 0.1 M NaCl. The pH was adjusted to 2.85 by adding 0.0025 M HCl. A precipitate was formed and this was centrifuged down at 4000 rev./min. The supernatant was decanted and amounts of alginate in soluble fraction, referred to as fraction B, and in the final residue, referred to as fraction C, were determined by the phenol-sulphuric acid reaction as men-

**RESULTS AND DISCUSSION**

Table I shows the percentage yield of alginates extracted from the seaweeds samples by the modified methods of Haug (1959) and the moisture content. Values obtained for alginate extracted in 1% Na\textsubscript{2}CO\textsubscript{3} were in good agreement with reports of earlier studies (Wedlock et al., 1986a; Omar and Ghani, 1986). There was no significant difference in the yield of alginate extracted in 1% or in 3% Na\textsubscript{2}CO\textsubscript{3} solution. However, the yield obtained from young *Sargassum* specimen was found to be slightly higher than from mature specimen. The extraction procedure used in this studies deviates from the standard method (Haug, 1959) by omitting the acid treatment; a previous report (Wedlock et al., 1986a) has demonstrated that this is a valid procedure for the species investigated here. Studies showed that alginate of young *Sargassum* spp. had a lower moisture content.

Table 2 gives the block composition and M/G ratios of alginate samples. Results are expressed as percentage of alginate found in appropriate fractions, that is, alginate soluble and insoluble at the indicated pH. Fraction A, which refers to solubilised alginate fraction in boiling 0.3 M HCl, corresponds to the poly (\(\beta\)-D-mannuronate-\(\alpha\)-L-guluronate) block which is the portion of alginate most labile to acidic hydrolysis. Fraction B corresponds to poly (\(\beta\)-D-mannuronate) block and was soluble at pH 2.85, while fraction C, the most stable portion and insoluble at pH 2.85, refers to the poly (\(\alpha\)-L-guluronate) block. M/G ratio was calculated from the poly (\(\beta\)-D-mannuronate) and poly (\(\alpha\)-L-guluronate) fractions, assuming that the alternating block (\(\alpha\)-L-guluronate)frac-

**Intrinsic viscosity \([\eta]\)**

Intrinsic viscosities of sodium alginate solutions were determined in Cannon-Ubbelohde semimicro dilution viscometer, size 75, at 20° C. The solvent used was 0.2 M NaCl, and alginate samples were dialysed to equilibrium against the solvent in cellulose dialysis sac (type 250-9U). Dialysate was used as diluent. The final concentration of alginate was determined using the phenol-sulphuric acid reaction.
TABLE 1
Percentage yield and moisture content of alginates from different sources, extracted with 1% Na$_2$CO$_3$.

<table>
<thead>
<tr>
<th>Source of alginate</th>
<th>Yield (%)</th>
<th>Moisture (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Sargassum</em> sp (mature)</td>
<td>32.0</td>
<td>20.0</td>
</tr>
<tr>
<td><em>Sargassum</em> sp (mature)</td>
<td>33.0*</td>
<td>14.0</td>
</tr>
<tr>
<td><em>Sargassum</em> sp (young)</td>
<td>35.0</td>
<td>19.0</td>
</tr>
<tr>
<td><em>Padina</em> sp</td>
<td>18.5</td>
<td>20-30</td>
</tr>
<tr>
<td><em>Ascophyllum nodosum</em></td>
<td>20-30*</td>
<td>20-45</td>
</tr>
<tr>
<td><em>Laminaria hyperborea</em></td>
<td>13-24*</td>
<td>4</td>
</tr>
<tr>
<td><em>Macrocystis pyrifera</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Laminaria digitata</em></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note:
*extracted with 3% Na$_2$CO$_3$.

TABLE 2
Block compositions of uronates and M/G ratios in alginates from different sources

<table>
<thead>
<tr>
<th>Source</th>
<th>GG-Block (%)</th>
<th>MM-Block (%)</th>
<th>MG-Block (%)</th>
<th>M/G</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Sargassum</em> sp (mature)</td>
<td>42</td>
<td>20</td>
<td>38</td>
<td>0.64</td>
</tr>
<tr>
<td><em>Sargassum</em> sp (young)</td>
<td>24</td>
<td>36</td>
<td>40</td>
<td>1.27</td>
</tr>
<tr>
<td><em>Padina</em> sp</td>
<td>36</td>
<td>28</td>
<td>36</td>
<td>0.85</td>
</tr>
<tr>
<td><em>Ascophyllum nodosum</em></td>
<td>14</td>
<td>15</td>
<td>61</td>
<td>1.25</td>
</tr>
<tr>
<td><em>Laminaria hyperborea</em></td>
<td>54</td>
<td>13</td>
<td>24</td>
<td>0.60</td>
</tr>
</tbody>
</table>

The actual M/G ratio in all cases might be slightly higher than results obtained by partial hydrolysis being reported here. This may be because the alternating poly (β-D-mannuronate-α-
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L-guluronate) block normally has a M/G ratio greater than 1.0; the range being 1.2-1.4, due to the occurrence of -MMG-and -MMMMG- sequence (Haug et al., 1967; Larsen, 1981). In addition, some of the poly (β-D-mannuronate) block might be solubilised during hydrolysis since they are more susceptible than the poly (α-L-guluronate) block (Haug et al., 1967).

In this study it was found that the M/G ratio for alginate from young Sargassum spp. was about twice that of mature Sargassum spp. A higher M/G ratio alginate found in young seaweeds was expected since during the early stage of seaweeds development, mainly mannuronic acids make up alginate chains. Mannuronic residues are later epimerised to guluronic acid by enzyme C5-epimerase at some later development stage (Larsen, 1981). As the algal tissues become older, more mannuronic acid being epimerised to guluronic acid and the M/G ratio of the alginate becomes smaller. The effect is to make the seaweed tissues stronger and to give the alginate a higher gel strength.

![Fig. 1: Plots of \(\eta_{sp}/c\) (O) and \(\ln \eta_{rel}/c\) (□) versus c, where c is concentration of alginate.](image)

The intrinsic viscosity, \([\eta]\), of alginate was obtained by plotting values of \(\eta_{sp}/c\) against c, or \(\ln \eta_{rel}/c\) against c, were \(\eta_{sp}\) and \(\eta_{rel}\) are specific and relative viscosities, respectively, and c is the alginate concentration in g/mL. These plots, on extrapolation to zero concentration, intersect at a point on ordinate to give the intrinsic viscosity, \([\eta]\). Figure 1 shows such plots for alginate extract from mature Sargassum spp., where \([\eta]\ = 412\ mL\) was obtained. Intrinsic viscosities for various alginate samples measured in 0.2 M NaCl are summarised in Table 3. It was found that alginate from Sargassum spp. possessed a higher intrinsic viscosity compared with Padina spp. Using 3% Na2CO3 solution as extractant resulted in a lowering of the viscosity of the alginate solution. An intrinsic viscosity of 625 mL/g was obtained for the alginate extract from Sargassum by the same method (Wedlock et al., 1986a). However, the alginate from the same source, when extracted by precipitation with an excess CaCl2 solution, was reported to possess an intrinsic viscosity of 635 mL/g (Wedlock et al., 1986b). It has been suggested that the viscosity property of all alginates is affected by method of extraction (Wedlock et al., 1986). Prolonging the period of extraction in higher Na2CO3 concentration also causes degradation of alginates.

Bleaching agents such as sodium hypochlorite and calcium hypochlorite are often used in industrial preparation of alginates, in order to improve the colour and appearance of the products. Addition of sodium hypochlorite, NaOCl, to the extract gave a clearer solution of sodium alginate, and the product obtained was pale yellow in colour. However, sodium alginate extracted using this technique was found to have a much lower intrinsic viscosity (i.e. \([\eta]\ = 210\ mL/g\)), when compared with extraction methods which did not employ NaOCl. It has been suggested that bleaching agents such as hypochlorite, due to its ability to form free radical intermediates in solution, could enhance the degradation of alginates in solution (Fasihuddin 1987). The low \([\eta]\) could be due to such degradation process.

Our analysis of an alginate sample extract from seaweed which was pre-treated with aqueous formaldehyde, showed a much higher \([\eta]\), where a value of 650 mL/g was obtained. Phenolic compounds have been implicated with the oxidative degradation of alginates through their ability to form free radical intermediates in solution, could enhance the degradation of alginates in solution (Fasihuddin B.A. et al., 1987). Formaldehyde also kills bacteria or micro-organism in seaweeds which could contri-


<table>
<thead>
<tr>
<th>Source</th>
<th>Extractant</th>
<th>mL/g</th>
<th>( \bar{M}_v )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sargassum</strong></td>
<td>1% Na(_2)CO(_3)</td>
<td>412</td>
<td>2.25 \times 10^5</td>
</tr>
<tr>
<td>(mature)</td>
<td>(untreated)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3% Na(_2)CO(_3)</td>
<td>400</td>
<td>2.17 \times 10^5</td>
</tr>
<tr>
<td></td>
<td>(untreated)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1% Na(_2)CO(_3)</td>
<td>210</td>
<td>1.05 \times 10^5</td>
</tr>
<tr>
<td></td>
<td>(treated with NaOCl)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1% Na(_2)CO(_3)</td>
<td>650</td>
<td>3.77 \times 10^5</td>
</tr>
<tr>
<td></td>
<td>(seaweeds pre-soaked</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>in formaldehyde)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Padina</strong></td>
<td>1% Na(_2)CO(_3)</td>
<td>312</td>
<td>1.64 \times 10^5</td>
</tr>
<tr>
<td></td>
<td>(untreated)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The presence of transition metal ions, such as Fe\(^{2+}\) or Fe\(^{3+}\), together with phenolic compounds would enhance free radical formation which causes depolymerisation of phycocolloids (Parson *et al.*, 1985). Therefore, removal of phenolic compounds prior to extraction in Na\(_2\)CO\(_3\) solution reduces the degradation of alginates. Results obtained here were consistent with the higher intrinsic viscosities obtained from formaldehyde treated samples.

Table 3 also summarizes the viscosity average molecular weights, \( \bar{M}_v \), calculated using the Mark-Houwink equation \([\eta] = K M^a\) (Wedlock *et al.*, 1986) where K and a are constants with values of 8.04 \times 10^{-3} g/mL and 0.88, respectively, for the viscosity of alginate solution measured in 0.2 M NaCl at 20°C.

Intrinsic viscosity of *Sargassum* alginate was also measured in various concentrations of NaCl and NaOH solutions, (*Figure-2*). It was found that intrinsic viscosities increased as the solvent concentration was decreased. \([\eta]\) equals to 520 and 400 mL/g were obtained in 0.05 M NaCl and 0.5 M NaCl, respectively. A similar trend occurred when viscosities were measured in dilute NaOH, where \([\eta]\) equals to 526 and 420 mL/g were obtained in 0.05 M NaOH, and 0.50 M NaOH, respectively and this can be regarded as electroviscous effect because alginates behave as a typical polyelectrolyte.

**CONCLUSION**

In conclusion, it has been shown that mature *Sargassum* spp. obtained locally yielded quite a high quality alginate. This was based on its low
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M/G ratio, which is essential for the Ca\(^{2+}\) - mediated gel formation of strong and brittle gel. It was also shown that the industrial method which employs bleaching agents, such as sodium hypochlorite, in order to improve the appearance of the product, produced alginates of low molecular weight average, based on intrinsic viscosities measurement. Pretreatment of seaweed samples with a dilute formaldehyde solution gave alginates of high molecular weight average.

Alginates obtained from *Padina* had a lower molecular weight average than that from *Sargassum*. These studies also showed that *Sargassum* spp. which are found in abundance in Sabah intertidal waters, could become a commercial source of alginate.

REFERENCES


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