Commercial varieties of *Kappaphycus* and *Eucheuma* in Malaysia

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**ABSTRACT** The seaweed industry has been identified for priority development in Malaysia. The seaweeds commercially farmed for carrageenan belong to the genera *Kappaphycus* Doty and *Eucheuma* J. Agardh. At least six varieties of *Kappaphycus* and *Eucheuma* are found in the farms around Sabah, east Malaysia. These seaweeds produce carrageenan with gel strength ranging from 250 to 550 g.cm⁻². This paper provides a simple description of gross morphological features and illustrations that may be used in the field for differentiating the main seaweed varieties cultivated in Sabah.

**ABSTRAK** Industri rumpair laut telah dikenalpastikan sebagai keutamaan untuk dibangunkan di Malaysia. Rumpair laut yang dikultivasi secara komersial untuk penghasilan karageenan adalah daripada genera *Kappaphycus* Doty dan *Eucheuma* J. Agardh. Lebih kurang enam jenis *Kappaphycus* dan *Eucheuma* ditemui dari ladang di Sabah, Malaysia Timur. Rumpair laut ini menghasilkan karageenan yang mempunyai kekuatan gel daripada 250 sehingga 550 g.cm⁻². Kertas ini memberikan gambaran ringkas terhadap ciri-ciri morologi kasar berserta ilustrasi yang boleh digunakan di lapangan untuk membezakan jenis-jenis rumpair laut utama yang dikultivasi di Sabah.

*(Keywords: Kappaphycus, Eucheuma, carrageenan, gel strength, seaweed farms.)*

**INTRODUCTION**

The seaweed farming areas of East Malaysia contributes to the high global production of carrageenan by the Coral Triangle (Figure 1). The Coral Triangle is bordered by six nations. In 2007, the global production of carrageenophytic seaweeds (*Kappaphycus* and *Eucheuma*) was more than 200,000 metric tonnes (MT) DW [1], which sold for between USD800 to 1200 per MT DW. The global demand for raw carrageenophytes is projected to reach 400,000 MT DW by 2012, with the Coral Triangle countries contributing 71% of the global production.

In 2009, the total production of *Kappaphycus* within the Coral Triangle was 200,000 MT, and the production by country is as follows: Indonesia (54%); Philippines (40%); Malaysia (3%); Solomon Islands (1%); and Timor Leste (1%). Papua New Guinea has just started trial plots in the Atalau area in August 2010. The populations within the Coral Triangle are also amongst the poorest in the region, and seaweed farming is an important avenue for poverty eradication.

Seaweed farming is one of three priority development areas for the agriculture sector in Malaysia. The targeted production of the 1200 families (Figure 2), around Semporna, the 2009 production was 6,000 MT at 40% moisture content. The farms are located in Semporna, Lahad Datu, Kunak, Banggi and Kudat [2]. The seaweeds commercially farmed for carrageenan belong to the genera *Kappaphycus* Doty and *Eucheuma* J. Agardh.

**TAXONOMY OF EUCHEUMA**

The domestication of *Eucheuma* took place in 1973 in the Philippines [3] with the common names of *cottonii*, *spinorum* or *gelatinus* used by the industry. As commercial interest in these carrageenophytes increased, it became important to have proper taxonomy and nomenclature of this genus. *Eucheuma* was established by J.G. Agardh [4] and *Eucheuma denticulatum* (Burman) Colins et Hervey is accepted as the type for the genus. *Eucheuma* identification was based on the presence of three types of tissues in the rigid thallus: (i) rhizoidal medullary core, (ii) round medullary cells, (iii) cortex comprising radiating filaments of small, elongated cells [5]. Doty and Norris (1985) [6] provided a practical key to 15 *Eucheuma* species that were major sources of carrageenan. Different species of *Eucheuma* produce different carrageenans (described as alpha, beta, gamma, iota, lambda, kappa, mu and nu) [5]. Using this
rearranged sections:

(i) E. sect. Eucheuma [Type: Eucheuma denticulatum (Burman) Collins et
Hervey]
(ii) E. sect. Anaxiferae Weber-van Bosse, emend. (Type: Eucheuma arnoldii
Weber-van Bosse)
(iii) E. sect. Gelatiformia [Type: Eucheuma gelatinae (Esper) J.
Agardh]
(iv) E. sect. Cottoniformia (Type: Eucheuma alvarezii Doty)

The Eucheuma sect. Eucheuma (synonym Eucheuma sect. Axiferae Weber-van Bosse is
distinguished by an axial core of rhizoids, and includes E. denticulatum (Burman) Collins et
Hervey), E. spinosum (Linnaeus) J. Agardh, which
produce iota carrageenan. These species are
commonly referred to as “spinosum” by the
industry.

The Eucheuma sect. Anaxiferae has whorls of
spines on indeterminate and determinate branches,
absence of axial hyphae and produce iota-
carrageenan.

The Eucheuma sect. Gelatiformia is distinguished by
strap-like segments with compressed axial core
of hyphae and the production of kappa-carrageenan.

The Eucheuma sect. Cottoniformia is characterised
by a core of irregular, thin-walled axial hyphae and
the production of kappa-carrageenan. E. alvarezii
and E. striatum are included this section and are
commercially grouped into the “cottonii” although
the E. cottonii Weber-van Bosse is not included in
this section. Secondary branches are abundant in E.
striatum but usually absent in E. alvarezii.

SEPARATION OF KAPPAPHYCUS FROM
EUCHEUMA

In 1988, Doty revised the four sections of
Eucheuma by Doty and Norris (1985) [6] by
recognising a new tribe Euchenumatoideae (type
genus: Eucheuma J. Agardh) and a new genus
Kappaphycus (type species: E. alvarezii Doty).
This tribe comprises Eucheuma with three sections
(E. sect. Eucheuma; E. sect. Anaxiferae; and E.
Gelatiformia) and Kappaphycus. Kappaphycus is
distinguished from the rest by absence of whorls of
spines, rarely with opposite branching, cystocarps
on main axes, and the production of kappa-
carrageenan. In cross-section, the thallus
comprises an inner and outer cortex; the outer
cortical cells are radially elongated and pigmented;
the inner cortical cells are also radially elongated
and thick-walled. The cells get bigger towards the
inside to form the medulla. The medullary cells are
isodiametric and form a pseudoparenchymatous
tissue, with a central core (especially evident at the
tips) of filaments forming an axial hypha (Figures 3,
4). In rarely found fertile thalli, cystocarps may be
found scattered over the surface of the thallus
(Figure 5).

Kappaphycus comprises the following species:

(i) K. alvarezii (Doty) Doty (Basionym:
E. alvarezii Doty); collected from
Karindingan Island on Creagh Reef,
near Semporna
(ii) K. inerme (Smitt) Doty (Basionym: E.
ierme Schmitz); from Tanzania
(iii) K. striatum (Smitt) Doty (Basionym:
E. striata Smitt) or commonly as E.
striatum; from Zanzibar, east Africa,
Indonesia, eastern Sabah, Philippines
(iv) K. procrusteanum (Kraft) Doty
(Basionym: E. procrustanum Kraft);
central Philippines
(v) K. cottonii (Weber-van Bosse) Doty
(Basionym: E. cottonii Weber-van
Bosse); Tanzania, Hainan Island,
Philippines, Guam, Mauritius.

Eucheuma, distinguished by indeterminate growth
with spine-like determinate lateral branches
comprises:

(i) E. denticulatum (N.L. Burman)
Collins et Hervey, from Mozambique,
Indonesia, Sabah, Philippines, New
Caledonia
(ii) E. serra (J. Agardh); Mauritius
(iii) E. isiforme (C.Agardh) J. Agardh;
Caribbean
(iv) E. uncinatum Setchell et Gardner;
Gulf of California, Mexico
(v) E. arnoldii Weber-van Bosse;
Queensland, Ryukus, Taiwan
(vi) E. amakusaensis Okamura; Japan,
Taiwan, Philippines
(vii) E. gelatinae (esper) J. Agaeh;
Philippines, south China
(viii) E. periclim Doty; Taiwan
(ix) E. kriftianum Doty; central Indonesia
(x) E. speciosum (Sonder) J. Agardh;
western Australia
(xi) E. odontoporum Boergesen;
Mauritius, east Africa
(xii) E. platycladum Schmitz; east Africa.

Three main varieties of K. alvarezii (E. alvarezii)
recognized are K. alvarezii var. alvarezii with
simple, small, open thallus; K. alvarezii var.
tambalang with bushy thallus comprising smaller
indeterminate axes and short segments; K. alvarezii
var. ajak-assi with long main axis [3]. K. alvarezii var. alvarezii grows on reef flat limestone rocks; K. alvarezii var. tambalang on turbulent water of shallow reef flats; and K. alvarezii var. ajak-assi prefers flowing water with high nutrient and light. Zucharello et al. (2006) [7] used molecular analysis based on the mitochondrial cox2-3 and plastidal RubisCo spacers to investigate the systematics and genetic variation of 137 samples of commercial Kappaphycus and Eucheuma, including some wild strains.

Kappaphycus was shown to be distinct from Eucheuma; K. alvarezii ("cottonii") and K. striatum ("sacol") are genetically distinct; however the markers did not distinguish all the morpho-types of K. alvarezii. A larger sample size as well as the use of more variable molecular markers are needed to solve the identification of the morpho-types of Kappaphycus and Eucheuma.

FARMED KAPPAPHYCUS AND EUCHEUMA IN SABAH

Many varieties of Kappaphycus and Eucheuma are found in the farms around Sabah, east Malaysia. These varieties, their common names and their gel strengths, as determined by using the Steve Plotter (Danisco’s Protocol) on 1.2% gel, at the Omni-Gel Laboratory, Sabah are given in Table 1. About six varieties were collected by Dr. Gan of Omni-Gel Company, with gel strength ranging from 250 to 500 g.cm⁻². The brown tambalang variety is popular because of the high gel strength. The following is a simple description of gross morphological features that may be used in the field for differentiating the main varieties cultivated in Semporna, Malaysia.

i) K. alvarezii var. tambalang (Figures 6-9)

There are around three sub-varieties of this tambalang, named Green Tambalang, Brown Tambalang and Giant Tambalang. There is another known as Buaya Tambalang growing in deeper water.

The tambalang appears bushy with dichotomous to irregular branching. The long, cylindrical main branches are covered with lateral branches with pointed tips.

ii) Aring-aring (K. alvarezii) (Figure 10)

This variety has a finer thallus with very short lateral branches with pointed tips. The plant has a greener hue when grown in shallower (<1m) water compared to the brown colour when grown at 2m.

iii) Durian (K. alvarezii) (Figure 11)

This variety has cylindrical branches with wide angles between branches. The lateral branches are short, thick and appear as stiff broad spines, crowded near the tips of main branches. The whole plant looks like the durian fruit.

iv) Loving Beauty (K. alvarezii) (Figure 12)

This variety has a thallus morphology intermediate between the tambalang and durian varieties. The lateral branches are flexuous, located nearer the distal ends of main branches, and the tips may be rounded.

v) Flower (K. striatum var. sacol) (Figure 13)

The Flower or sacol variety has three sub-types with differing colour (viz. green, brown and red). The variety which is commonly farmed has a greenish hue to the brown colour. The compact cylindrical thallus is densely covered with very short lateral branches crowded near the tips of the main branches, with broad angles between main branches, and giving the whole plant the shape of a dense head of flowers. Associated with this is also the Katunai varieties (Green Katunai and Brown Katunai) (Figures 14-15).

vi) Spinosum (Eucheuma) (Figure 16)

This is probably E. denticulatum. The thallus is irregularly branched. The long cylindrical branches are covered with short spines throughout distinguishing it from the generally smooth cylindrical thallus of Kappaphycus.

UTILISATION OF KAPPAPHYCUS AND EUCHEUMA

The Kappaphycus and Eucheuma farmed in east Malaysia is mainly used for carrageenan production. Two factories in Sabah were started in 2000 to produce semi-refined carrageenan, including carrageenan chips. Tacara is located in Morotai, Tawau while Omi-Gel is located at Jalan Kemiri, Semporna. The first successful farm for Kappaphycus (tambalang variety) in Peninsular Malaysia, has been established on Pangkor Island by Mr. Beh Wong King.

The farm has only been operating for less than a year and about 400kg FW can be harvested from 200m monolines in one month (pers. comm., Mr. Beh). The seaweed is presently dried for sale as a herbal material. Figures 17-18 show the monolines and the product. Traditionally, the Kappaphycus
**Figure 1:** Map showing the Coral Triangle (shaded) which comprises six countries: 1: Indonesia; 2: Philippines; 3: Solomon Islands; 4: Papua New Guinea; 5: Malaysia; 6: Timor Leste. (SeaPlant.net)

**Table 1:** List of *Kappaphycus* and *Eucheuma* varieties farmed in Malaysia and their gel strengths.

<table>
<thead>
<tr>
<th>Seaweed variety (common name)</th>
<th>Scientific name</th>
<th>Collection Locality</th>
<th>Gel strength using the Steve Plotter Method (1.2% gel) g.cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green tambalang</td>
<td><em>K. alvarezii</em> var. <em>tambalang</em></td>
<td>Semporna</td>
<td>&gt;550</td>
</tr>
<tr>
<td>Brown tambalang</td>
<td><em>K. alvarezii</em> var. <em>tambalang</em></td>
<td>Semporna</td>
<td>&gt;550</td>
</tr>
<tr>
<td>Giant tambalang</td>
<td><em>K. alvarezii</em> var. <em>tambalang</em></td>
<td>Semporna</td>
<td>N/A</td>
</tr>
<tr>
<td>Buaya tambalang (deeper water)</td>
<td><em>K. alvarezii</em> var. <em>tambalang</em></td>
<td>Semporna</td>
<td>N/A</td>
</tr>
<tr>
<td>Airing-aring (grown at &lt;1m)</td>
<td><em>K. alvarezii</em></td>
<td>Semporna</td>
<td>&gt;500</td>
</tr>
<tr>
<td>Airing-aring (grown at 2m)</td>
<td><em>K. alvarezii</em></td>
<td>Semporna</td>
<td>&gt;500</td>
</tr>
<tr>
<td>Durian</td>
<td><em>K. alvarezii</em></td>
<td>Semporna</td>
<td>&gt;450</td>
</tr>
<tr>
<td>Loving beauty</td>
<td><em>K. alvarezii</em></td>
<td>Semporna</td>
<td>&gt;550</td>
</tr>
<tr>
<td>Flower (sacol)</td>
<td><em>K. striatum</em> var. <em>sacol</em></td>
<td>Semporna</td>
<td>&gt;550</td>
</tr>
<tr>
<td>Katunai (green)</td>
<td><em>K. striatum</em></td>
<td>Semporna</td>
<td>N/A</td>
</tr>
<tr>
<td>Katunai (brown)</td>
<td><em>K. striatum</em></td>
<td>Semporna</td>
<td>N/A</td>
</tr>
<tr>
<td>Spinosum</td>
<td><em>E. denticulatum</em></td>
<td>Semporna</td>
<td>&gt;250</td>
</tr>
</tbody>
</table>
Figure 2: *Kappaphycus* farm in Semporna, Sabah. (Photo credit: Mushidi bin Hassan)

Figure 3: Cross-section of *Kappaphycus* thallus. C: Cortex made up of smaller outer cortical cells and inner radially elongated cells; M: Medulla made up of large rounded cells, with a central core narrow filaments forming the axial hyphae.

Figure 4: Cross-section of *Kappaphycus* thallus. C: Cortex, made of smaller radiating cortical cells M: Pseudoparenchymatous medulla, made of larger, rounded cells mixed with smaller cells.
**Figure 5**: The reproductive structures known as cystocarps (carposporangia) are scattered all over the surface of the *Kappaphycus* thallus.

**Figure 6a**: *Kappaphycus alvarezii* var. *tambalang* (Green tambalang)

**Figure 6b**: *Kappaphycus alvarezii* var. *tambalang* (Green tambalang)
Figure 7a: Kappaphycus alvarezii var. tambalang (Brown tambalang)

Figure 7b: Kappaphycus alvarezii var. tambalang (Brown tambalang)

Figure 8: Kappaphycus alvarezii var. tambalang (Giant tambalang)

Figure 9a: Kappaphycus alvarezii var. tambalang (Buaya tambalang)

Figure 9b: Kappaphycus alvarezii var. tambalang (Buaya tambalang)

Figure 10a: Kappaphycus alvarezii (Aring-aring)
Figure 10b: *Kappaphycus alvarezii* (*Aring-aring*, < 1 meter depth)

Figure 10c: *Kappaphycus alvarezii* (*Aring-aring*, > 2 meter depth)

Figure 11: *Kappaphycus alvarezii* (Durian)

Figure 12: *Kappaphycus alvarezii* (Loving Beauty)

Figure 13: *Kappaphycus striatum* var. *sacol* (Flower)

Figure 14: *Kappaphycus striatum* var. *sacol* (Katunai green)
Figure 15: *Kappaphycus striatum* var. *saocol* (Katunai brown)

Figure 16a: *Eucheuma denticulatum* (Sinoreum)

Figure 16b: *Eucheuma denticulatum* (Sinoreum)

Figure 17: The monocline culture of *Kappaphycus* in Pulau Pangkor, Peninsular Malaysia

Figure 18: A salad made from freshly harvested *Kappaphycus* from the Pulau Pangkor farm.

Figure 19: Seaweed herbal drink
The maximum production from Semporna is around 250 to 350 MT DW per month. Biomass increases from the initial 0.1 to 0.2 kg per stocking bunch to 0.5 to 0.7 kg in 45 days. The maximum production capacity in Semporna is around 1.5 MT per hectare per month. The harvested seaweed is sun dried on the platforms of houses built on the reefs and sold with moisture content of 38 to 50%. Current selling price fluctuates around RM2.80 (USD 0.85) for moisture content of 50%.

Together with other seaweeds like Caulerpa, Ulva, and Gracilaria which are collected from the wild, the farmed Kappaphycus is sold in the local markets in Sabah for consumption as salads, soups and puddings [9]. Recently, health drinks, cordials, jelly cups, jams, chilli sauce and shampoo, have been produced from the Kappaphycus (Figures 19-21). Three patents have been filed in Malaysia on the use of the seaweeds for enhancing hair growth, wound-healing and anti-cancer pharmaceuticals.

CONCLUDING REMARKS

It is the objective of this short communication to review the various varieties of Kappaphycus and Eucheuma presently farmed in Malaysia. This is not a complete taxonomic nor systematic account; better understanding of the taxonomy of the many varieties described here can only be obtained through molecular analysis. While it has been shown that gel strength may differ amongst the many varieties, it should be remembered that many factors influence both the growth and chemical composition of seaweeds. Hurtado et al. (2008) [10] showed that stocking density, culture period, and water depth affects the growth rate, carrageenan content and molecular weight of K. striatum var. sacol.

The best conditions recommended for sacol is stocking density of 500g per m per monoline at a water depth of 50 to 100cm for 30 days of culture. Diseases like the ice-ice caused depolymerisation of the carrageenan and resulted in decrease in gel strength as well as in carrageenan yield, viscosity and increase in syneresis index, in K. striatum var. sacol [11]. Epiphyte infestations have also been associated with reduced seaweed production and reduced carrageenan quality [12]. The epiphytic Neospirulina produced “goose-bump” cortical swellings on the thallus of Kappaphycus alvarezi which resulted in pits which were then infected with opportunistic bacteria like Alteromonas, Flavobacterium and Vibrio as secondary infections.

To aid in the development of a viable, competitive carrageenan industry in Malaysia, the following actions are recommended:

- Improved breeding selection.
- To address this, DNA fingerprinting methods have to be developed. Complete database of phycocolloid characteristics (type, yield, gel strength), growth requirements, disease and epiphyte resistance, etc.

- Strain improvement focusing on disease resistance, good carrageenan quality and even adaptation to climate change.

- Use Recombinant techniques in addition to traditional hybridization and selection methods. Generate ESTs or sequence the genome of Kappaphycus. The mining of useful genes will lead to strain improvement and discovery of new products.

- Improved farming methods. Develop epiphyte control, nurseries for spore, tissue culture and seed production. Develop co-culture of seaweeds with shellfish, fish and other seafood species, as well as integrated aquaculture systems.

- New downstream products. Formulate new value-added products; eg, food, feed, cosmeceuticals, nutraceuticals, beverages, confectionaries, etc.

- Increased farming area and formulate farmer motivation and training activities.

The industry requires sources of consistent carrageenan quality; pure kappa-carrageenan or pure iota-carrageenan, not mixed together, as is often encountered in the market [13]. The availability of a good database and key to the various varieties of Kappaphycus and Eucheuma farmed in Malaysia, will allow our farmers to select and focus on the best varieties for each type of carrageenan. Cooperation between the industry, the farmers, the relevant government departments and the university researchers, is essential to provide this very important element necessary for the development of a viable and competitive seaweed industry for Malaysia.

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Figure 20: Seaweed chilli sauce

Figure 21: Seaweed shampoo