DMMMSU RESEARCH AND EXTENSION JOURNAL
Issue 1, December 2017 ISSN: 0119-2035
Pages: 54-65 https://doi.org/10.62960/dmmmsu.v1i.9

Research Article

Screening and characterization of agar of selected Agarophytes of La Union

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Keywords: agar, agarophytes, gelling and melting temperatures, gel strength
sulfate content

ABSTRACT

Agars of five (5) agarophytes of Balaoan and three (3) agarophytes of Sto. Tomas, La Union were screened and characterized based on yield (%), gelling and melting temperatures (°C), gel strength (g/cm^2), rupture force (g), cohesiveness (g)and sulfate content (%). Agars of Balaoan agarophytes significantly differed in all physico-chemical properties considered. Gelling temperature, gel strength, rupture force, cohesiveness and sulfate content significantly differed among Sto. Tomas agarophytes. Agars of *Gelidiella acerosa* of both sources were comparable in terms of yield melting temperature and sulfate content. Likewise, agars of *G. coronopifolia* were comparable in yield, gelling and melting temperatures, gel strength, rupture force, cohesiveness and sulfate content. Relationships existed among the physicochemical properties ranged from negative weak to positive strong.

Introduction

In our country today, much of the research and development efforts are directed towards the development of the agar industry. The development potentials of the industry are primarily based on the availability of local species which can produce large biomass and good quality colloid. Phycocolloids are carbohydrates or polysaccharides that have the ability to give viscosity, gel strength and stability to aqueous mixtures, solutions and emulsions. With such properties, they play increasingly important roles in the productions of processed food, dairy products, cosmetics, drugs, fertlizers, animal feeds and other valuable commodities. The highest –priced phycocolloid, according to Chandrkrachang and Chinadit (1988), is agar which is a sulphated galactan produced from red seaweeds.

How to cite:

Mamaril E. F. (2017). Screening and characterization of agar of selected Agarophytes of La Union. DMMMSU Research and Extension Journal, 1: 54 – 65. DOI: 10.62960/dmmmsu.v1i.9

There are large numbers of locally available species like *Gracilaria* species, *Gelidiella* species and other species which can be tapped for agar production. The agarophytes, however, are unique for the fact that species differ in their yields and quality of agar and thus for the industry to really prosper, it must utilize species which are characterized by high and very good quality agar. Agar, a traditional gelling agent, is a mixture of polysaccharides which is soluble in hot water and becomes insoluble at room temperature. One of its special important characteristics is gel formation at very low concentration.

The most important properties which are to be considered when determining the quality of an agar for food, tissue culture or bacteriological use are gel strength, gelling and melting temperatures, sulfate and methoxyl contents, clarify of the solution and ash (Chandrkrachang and Chinadit,1988). An agar of high gel strength is always preferred for food. For bacteriological media, a gel strength of 300-400 g/cm^2 at 1% concentration is acceptable. (Chandrkrachang andChinadit,1988). Agar extracted from *Gracilaria* usually have low gel strength and high viscosity. Gel strength varies with species, location, season, extraction method and the geltester used (Hoyle,1975). According to the observation made by Santos (1980), the gelling temperature as well as the melting temperature of 1.5 concentration of agar vary according to the seaweed source, the method of preparation and the purity if the sample. The gelling temperature of the agar solution ranges from 30°C to 50°C and the melting temperature from 82°C to 92°C.

Generally, this study aimed to screen and characterize the quality of agar of selected agarophytes of Balaoan and Sto. Tomas, La Union. Specifically, to: (1) determine the physicochemical properties of agar of selected agarophytes as to: [a] yield, [b] gelling and melting temperature, [c] gel texture (represented as gel strength rupture force and cohesiveness), [d]sulfate content; (2) compare the quality of agar of selected agarophytes of two sources, and (3) determine the relationship existed among the physicochemical properties.

Materials and Methods

Materials

Five (5) agarophytes *(Gelidiella acerosa, Gracilaria coronopifolia, Gracilaria euheumoides, Gracilaria salicornia and Gracilaria verrucosa)* were collected from (Paraoir) Balaoan, La Union and three (3) agarophytes *(G. acerosa, G. coronopifolia and G. verrucosa)* from Sto. Tomas, La Union. All seaweed samples were cleaned of foreign matters, washed thoroughly and bleach-dried until light brown color using sun-plain water method.

Agar Extraction

Each seaweed species was subjected to extraction following the methods described by Montaño et al. (1996) using 10% sodium hydroxide solution for the alkali treatment and neutralized with glacial acetic acid. Samples were washed thoroughly until free of acid and boiled. Gel was extracted, solidified and frozen overnight. Thawed the next morning and dried from 50°C to 60°C in an oven. Pulverized and packed in plastic air-tight containers.

Agar Quality Assessment

a. %, Yield determination: Yield of agar determined using the formula:

$$\% \text{ Yield} = \frac{\text{wt. of dried agar}}{\text{wt. of dried seaweed sample}} \text{ x } 100$$

b. Gelling and melting temperatures, °C

These properties of agar gels were determined at the Seaweed Chemistry Center – UP Diliman, Quezon City using the methods modified from J.N.C. Whyte J.R. and Englar (1980).

c. Gel texture

Gel texture (represented as gel strength, rupture force and cohesiveness) was likewise, conducted at the Seaweed Chemistry Center-UPDiliman Quezon City using the methods modified from R.L. Veroy and M.N.E. Montaño (1981).

d. Sulfate, %

The FAO Method (Food and Chemicals Codex, 1981) was used to determine the sulfate content of the agar.

Analysis of Data

To determine significant differences among treatment means, Analysis of Variance (ANOVA) was used while t-Test was adopted for comparison of data obtained among agarophytes of the two (2) sources. For significant results, further analysis using the Duncan Multiple Range Test was conducted. To determine relationships among the physicochemical properties, correlation coefficient (r) analysis was likewise, conducted.

Results and Discussion

Yield (%) of agar

Table 1. showed the yields of agar of agarophytes of two (2) sources.

Agar yields of Balaoan agarophytes ranged from 8.67% to 23% *G. coronopifolia* recorded the highest yield while *G. salicornia* the lowest yield. Differences existed among the yields of agar were significant. However, agar yields of *G. coronopifolia,* Gelidiella *acerosa* and *G. verrucosa* were comparable but not comparable to *G. eucheumoides*, and *G. salicornia.*

For Sto. Tomas agarophytes, yields ranged from 21.17% to 23.67% *G. coronopifolia* recorded the highest yield while *G. verrucosa* the lowest yield. Differences existed among the yields were not significant. It implied that the yields of the three (3) agarophytes were comparable. t -Test revealed yields of agar of agarophytes common to both sources were comparable.

Table 1. Yields (%) of agar.

Agarophytes	Sources	
	Balaoan	Sto. Tomas
Gelidiella acerosa	22.33[a]	22.17
Gracilaria coronopifolia	23.0[a]	23.67
G. eucheumoides	13.5[b]	*
G. salicornia	8.67[bc]	*
G. verrucosa	21.0[a]	21.17

* *no sample*
Means (within a column) followed by a common letter are not significantly different at 0.05 level.

Values recorded in this study for *G. acerosa* of both sources were observed to be within the range from 12.49% to 26.69% by Montaño et al. (1991). Yields for *G. coronopifolia* of both sources were observed to be lower compared to those reported by Hurtado-Ponce et al. (1988) at 35.82%, however, values were noted to be within the reported yield range from 19.0% to 34.34% by Montano et al. (1991). For *G. verrucosa* of both sources, yields recorded in this study were observed to be lower than the values reported by Hurtado-Ponce et al. (1988) at 24.13%. However, yields were observed to be higher than those reported by Montaño et al. (1991).For *G. euheumoides*, yield was observed to be much lower than the value reported by Hurtado-Ponce et al. (1998) at 33.758% and Montano et al. (1991) from 16.28% to 31.75%.Yield of G. *salicornia* was observed to be higher compared to the yield reported by Montano et al. (1991) at 6.67%.

As to the relationship of agar yield with the physicochemical properties, gelling temperature (r = 0.838),melting temperature (r = 0.891) gel strength (r = 0.986) rupture force (r = 0.986) and cohesiveness (r = 0.999) had strongly affected the agar yield of *G. acerosa* of Balaoan while the agar yield of *G. acerosa* of Sto. Tomas was strongly affected by gelling temperature (r = -0.981), rupture force (r = -0.929) and cohesiveness (r = -0.952). Yield of *G. coronopifolia* of Balaoan was strongly affected by cohesiveness (r = 0.976) while the yield (of *G. coronopifolia*) at Sto. Tomas was strongly affected by gelling temperature (r = 0.838), melting temperature (r = -0.981), gel strength (r = 0.986), rupture force (r = 0.986) and cohesiveness (r = 0.999). Cohesiveness (r = -0.999) strongly affected the agar yield of *G. verrucosa* of Balaoan while the yield at Sto. Tomas was not affected by any of the physico-chemical properties. Agar yield of *G. eucheurnoides* was strongly affected by gelling temperature (r = 0.866), melting temperature (r = 0.866) gel strength (r = 987) and rupture force (r = 0.986). For *G. salicornia*, agar yield was strongly affected by melting temperature (r = -0.899), gel strength (r = -0. 910). rupture force (r = -0.912) and sulfate (r = -0.942).

Gelling temperature (°C) of agar

Table 2. showed the gelling temperatures of agar of agarophytes of two (2) sources. Agar gelling temperatures (°C) of Balaoan agarophvtes ranged from 34.0 °C to 40 °C. *G.acerosa*, *G. salicornia* and *G. verrucosa* recorded the highest while *G. coronopifolia*, the lowest gelling temperature. The gelling temperatures of agar differed significantly. However, further analysis using DMRT, gelling temperatures of agar of *G.acerosa*. *G. salicornia, G. verrucosa* and *G. eucheumoides* were comparable.

Table 2. Gelling temperatures (°C) of agar.

Agarophytes	Source	
	Balaoan	Sto. Tomas
Gelidiella acerosa	40.0[a/a]	36.66[a/b]
Gracilaria coronopifolia	34.0[b]	35.0[a]
G. eucheumoides	39.33[a]	*
G. saliconia	40.0[a]	*
G. verrucosa	40.0[a/a]	32.33[b/b]

* no sample

Means (within a column) followed by a common letter arc not significantly different at 0.05 level.

For Sto. Tomas agarophytes, gelling temperatures ranged from 32.33°C to 36.66 °C. *G. acerosa* recorded the highest while *G. verrucosa,* the lowest gelling temperature. Differences in the agar gelling temperature were significant. However, gelling temperatures of *G. acerosa* and *G. coronopifolia* were comparable. t-Test revealed that gelling temperatures of agar of agarophyte common to both sources were comparable for *G. coronopifolia* but not comparable for *G. acerosa* and *G. verrucosa*. It implies that the gelling temperatures of *G. acerosa* and a *G.* verrucosa of Balaoan were significantly higher than of Sto. Tomas.

Values of gelling temperature recorded in this study for *G. acerosa* of both sources were observed to be within the temperature range reported by Santos (1980) from 30°C to 50°C. Armisen and Galatas (1987) reported a wider range from 34°C to 43°C for the gelling temperature. Santos (1980) observed that the gelling temperature as well as the melting temperature of agar vary according to the seaweed source, the method of preparation and the purity of the sample. For the *G. coronopifolia* of both sources, it was noted that the gelling temperatures were within the temperature range from 30°C to 50°C as reported by Santos (1980). Values recorded by Armisen and Galatas (1987) are within the temperature range from 32°C to 39°C where agar congeals/solidifies. Values of gelling temperature recorded in this study for *G. verrucosa* of both sources were noted to be within the temperature range reported by Santos (1980) from 30°C to 50°C. However, gelling temperature of G. verrucosa of Balaoan was higher than the temperature ranges from 32°C to 39°C where agar congeal/solidifies while that of Sto. Tomas. the recorded gelling temperature was within the temperature range.

For *G. eucheumoides* and *G. salicornia,* gelling temperatures recorded were noted to be within the temperature range reported by Santos (1980) from 30°C to 50°C and those reported by Armisen and Galatas (1987) from 34°C to 43°C. However, values were higher than 33.50°C as reported by Hurtado — Ponce et al. (1988) and the temperature range from 32°C to 39°C where agar congeals/solidifies. The gelling temperature of *G. acerosa* of Balaoan was strongly affected by cohesiveness (r = 0.821 while rupture force (r = 0.998), cohesiveness (r = 0.992), and sulfate content (r = -0.855) had strongly affected the gelling temperature of *G. acerosa* of Sto. Tomas. For the *G. coronopifolia* of Balaoan, gelling temperature was strongly affected by melting temperature (r = 0.866), gel strength (r = -0.998) and rupture force (r = 0.843), while cohesiveness (r = 0.871) had strongly affected the gelling temperature of *G. coronopifolia* of Sto. Tomas. Gelling temperature of *G. verrucosa* of Balaoan was strongly affected by gel strength (r = 0.806), rupture force (r = 0.803) and sulfate (r = 0.994) while the *G. verrucosa* of Sto.

Tomas was strongly affected by melting temperature (r = 0.996), rupture force (r = 1.0) cohesiveness (r — 0.997) and sulfate (r = 0.985). For *G. eucheumoides,* gelling temperature

was strongly affected by gel strength (r = 0.934), rupture force (r — 0.935), cohesiveness (r = 0.887) and sulfate (r = 0.887) while *G. salicornia* was strongly affected by cohesiveness (r = 1.0).

Melting temperature (°C) of agar

Table 3. showed the melting temperatures of agar of agarophytes of two (2) sources. Agar melting temperatures of the Balaoan agarophytes ranged from 68.33 °C to 86.66 °C. *G. coronopifolia* recorded the highest while *G. verrucosa*, the lowest melting temperature. Differences in the melting temperatures of agar were significant. However, melting temperatures of *G. coronopifolia, G, salicornia, G, eucheurnoides* and *Gelidiella acerosa* were comparable but not comparable to *G. verrucosa*.

Table 3. Melting temperatures (°C) of agar.

Agarophytes	Source	
	Balaoan	Sto. Tomas
Gelidiella acerosa	83.66[a]	84.66
Gracilaria coronopifolia	86.66[a]	84
G. euheumoides	80.66[a]	*
G. salicornia	86.33[a]	*
G. verrucosa	68.33[b/b]	84.66 [a]

*no sample
Means (within a column and row) followed by a common letter are not significantly different at 0.05 level.

For Sto. Tomas agarophytes, melting temperatures of agar ranged from 84.0 °C to 84.66 °C. *G acerosa* and *G. verrucosa* recorded higher melting temperatures than *G. coronopifolia*. However, differences in the melting temperatures of agars were not significant. It implied that the melting temperatures of the three (3) agarophytes were comparable. t-Test, likewise, revealed that melting temperatures of agar of agarophytes common to both sources were comparable for *G. acerosa* and *G. coronopifolia* but not comparable to *G. verrucosa.* It implied that the melting temperature of *G. verrucosa* of Sto. Tomas was significantly higher than of Balaoan.

Values for melting temperature of *Gelidiella acerosa* of both sources were observed to be lower than the melting temperature required by the United States Pharmacoepia (USP) Standards at 85°C. However, values were found to be within those reported by Santos (1980) from 82°C to 92°C. For G. *coronopofilia* of both sources, melting temperatures were noted to be within those reported by Santos (1980) from 82°C to 92°C and higher than the values reported by Hurtado-Ponce et al. (1988) at 74.8°C. However, melting temperature of *G. coronopofilia* of Balaoan was within the USP Standards at 85°C while *G. coronopofilia* of Sto. Tomas was not within the required temperature. Melting temperatures of *G. verrucosa* were observed to be lower than the value required by USP Standards. However, the melting temperature of *G. verrocusa* of Sto. Tomas was noted to be within the temperature range reported by Santos (1980) and higher than the value reported by Hurtado-Ponce et al. (1988) at 83.7°C. For *G. verrucosa* of Balaoan, melting temperature was noted to be lower than both the value reported by Hurtado-Ponce et al. (1988) and temperature range reported by Santos (1980).Melting temperature of *G. eucheumoides* was found to be lower than those reported by Santos (1980) and the temperature required by the USP Standards. However, it was higher than the values reported by Hurtado-Ponce et al. (1988) at 76.5°C.For *G. salicornia*, melting temperature was

observed to be higher than the temperature required by USP Standards and within the temperature range reported by Santos (1980). However, it was higher than the values reported by Hurtado Ponce et al. (1988) at 74.2°C.

The melting temperature of *Gelidiella acerosa* of Balaoan was strongly affected by gel strength (r =-0.953), rupture force (r = -0.953) and cohesiveness (r = 0.904) while melting temperature of *Gelidiella acerosa* of Sto. Tomas was strongly affected by gel strength (r = 0.998). It was affected by sulfate (r = 0.734) moderately. For *G. coronopofilia* of Balaoan, melting temperature was strongly affected by gel strength (r = -0.842) rupture force (r = -0.842) and sulfate (r = -0.980) while *G. coronopofilia* of Sto. Tomas was strongly affected by gel strength (r = -0.953), rupture force (r = -0.953) and cohesiveness (r = -0.904).The melting temperature of *G. verrucosa* of Balaoan was weakly to moderately affected by the other physicochemical parameters while *G. verrucosa* of Sto. Tomas was strongly affected by rupture force (r = 0.996), cohesiveness (r = 0.999) and sulfate (r = 0. 966).Gel strength (r = 0.999) and rupture force (r = 0.999) had moderately affected the melting temperature of *G. eucheumoides* while *G. salicornia* was affected strongly by gel strength (r = 0.999), rapture force (r = 0. 999) and sulfate (r = 0.993).

Gel strength (g/cm^2) of agar

Table 4.0 showed the gel strength of agar of agarophytes of two (2) sources. For the Balaoan agarophytes, gel strengths of agar ranged from 38.36 g/cm^{2}to 486.6 g/cm^2. *Gelidiella acerosa* recorded the highest while *G. verrucosa,* the lowest gel strength. Differences in the gel strength of agar were significant. However, gel strength of agars of *Gelidiella acerosa* and *G. coronopifolia* were comparable. Gel strength of G. *eucheumoides* was not comparable to *G. salicornia* and *G. verrucosa* and *G. salicornia* was, likewise, not comparable to *G. verrucosa.*

Table 4. Gel strength (g/cm^2) of agar.

Agarophytes	Source	
	Balaoan	Sto. Tomas
Gelidiella acerosa	486.6$^{a/a}$	354.43$^{a/b}$
Gracilaria coronopifolia	466.4$^{a/a}$	162.03^{b}
G. euheumoides	197.8^{b}	*
G. salicornia	66.66^{c}	*
G. verrucosa	38.36$^{d/b}$	70.43$^{c/a}$

*no sample
Means (within a column and row) followed by a common letter are not significantly different at 0.05 level.

Gel strengths of agar of Sto.Tomas agarophytes ranged from 70.43 g/cm^2 to 354.43 g/cm^2. *Gelidiella acerosa* recorded the highest while *G. verrucosa,* the lowest gel strength. Significant differences existed among the values for gel strengths. However, gel strength of *Gelidiella acerosa* was significantly better than *G, coronopifolia* while *G. coronopifolia* has significantly better gel strength than *G. verrucosa.* t-Test revealed that gel strength of agar of Sto. Tomas agarophytes were significantly different from those of Balaoan agarophytes. It implies that agars of *Gelidiella acerosa* and *G. coronopifolia of* Balaoan produced stronger/more rigid gels. However, agar of *G.* verrucosa of Sto. Tomas produced a stronger/more rigid gel than of Balaoan.

Based on the gel strengths recorded in this study by *Gelidiella acerosa* of both sources, agar produced were categorized as Grade I (having gel strengths of 350g/cm^2 or more) according to the Japanese Specification of Processed Agar (Chandrkrachang and Chinadit, 1988). Values were likewise, observed to be within those reported by Montano et al. (1991) from 256g/cm^2 to 520g/cm^2.For *G. coronopofilia* of Balaoan, gel strength was observed to be higher than 350g/cm^{2}also categorized as Grade 1. The gel strength was, likewise, higher than the values reported by Montaño et al. (1991) at 216.0 g/cm^2 but lower than that of Hurtado-Ponce et at. (1988) at 523.5 g/cm^2. Gel strength of *G. coronopofilia* of Sto. Tomas was also observed to be lower than those reported by Hurtado-Ponce et al. (1988) and Montano et al. (1991). Gel strengths of *G. verrucosa* of both sources were observed to be lower than those reported by Montaño et al. (1991) from 304gi/m^2 to 428 g/cm^2 and. Hurtado-Ponce et al. (1988) at 970.54 g/cm^2. For *G. eucheumoides* gel strength was observed to be higher compared to those reported by Montano et al, (1991) from 144g/cm^2 to 181 g/cm^2 but not lower than Hurtado-Ponce et al. (1988) at 616.37 g/cm^2. *G. salicornia* produced an agar with a gel strength which was lower compared to that reported by Hurtado-Ponce.et al. (1988) at 642.41 g/cm^2.

Gel strength varies with species, location, season, extraction method and the gel tester used (Hoyle, 1975). An agar of high gel strength is always preferred for food. For bacteriological media, a gel strength of 300-400g/cm^2 at a one percent concentration is acceptable (Chandrkrachang and Chinadit, 1988). However, according to Yaphe and Duckworth (1972), agars extracted from *Gracilaria* species which form soft and elastic gels are mainly used in the food industry and are not for bacteriological application. The gel strength of *Gelidiella acerosa* of Balaoan was strongly affected by rupture force (r = 0.999) and cohesiveness (r = 0.991) while *Gelidiella acerosa* of Sto. Tomas was moderately affected by the sulfate content (r = -0.695).For *G. coronopifolia* of Balaoan, the gel strength was strongly affected by rupture force (r = 0.999) while *G. coronopifolia* of Sto. Tomas was strongly affected by rupture force (r = 0.999) and cohesiveness (r = 0.991).Rupture force (r = 0.999) and sulfate content (r = 0.865) had strongly affected the gel strength of *G. verrucosa* of Balaoan while gel strength of *G. verrucosa* of Sto. Tomas was moderately affected by rupture force (r = -0.544) and sulfate content (r = -0.679).The gel strength of *G. eucheumoides* was strongly affected by rupture force (r =0. 999) and moderately affected by cohesiveness r = 0.665) and sulfate content (r = 0.665).For *G. salicornia,* gel strength was strongly affected by rapture force (r = 0.999) and sulfate content (r =0.996).

Rupture force (g) of agar.

Table 5. showed the values of rupture force of agar of agarophytes of two (2) sources. Rupture force (g) of agar of Balaoan agarophytes ranged from 48.76g to 618.0g. *Gelidiella acerosa* recorded the highest while *G. verrucosa,* the lowest value for rupture force.

Table 5. Rupture force of agar.

Agarophytes	Source	
	Balaoan	Sto. Tomas
Gelidiella acerosa	618.0$^{a/a}$	450.13$^{a/b}$
Gracilaria coronopifolia	592.33^{a}	205.8^{b}
G. euheumoides	251.2^{b}	*
G. salicornia	84.63^{c}	*
G. verrucosa	48.76^{d}	89.5^{c}

* no sample

Means (within a column and row) followed by a common letter are not significantly different at 0.05 level.

Differences existed among the values of rupture force were significant. However, rupture force of agar of *Gelidiella acerosa* and *G. coronopifolia* were comparable but not comparable to *G. salicornia* and *G. verrucosa*. *G. salicornia* was likewise, not comparable to *G. verrucosa*.For Sto. Tomas agarophvtes, values of rupture force ranged. from 89.5g to 450.13g. *Gelidiella acerosa* recorded the highest while *G. verrucosa,* the lowest rupture force. Significant differences existed among the values recorded. However, DMRT further revealed that rupture force of *Gelidiella acerosa* agar was significantly higher than *G. coronopifolia* and *G. verrucosa.*

Rupture force of agar of agarophytes common to both sources were significantly different. It implied that rupture force of *Gelidiella acerosa* and *G. coronopifolia* agars of Balaoan were significantly higher than of Sto. Tomas. However, rupture force of *G. verrucosa* of Sto. Tomas was significantly higher than of Balaoan. Values of rupture force recorded by *G. coronopofilia* of both sources and *G. eucheumoides* were observed to be higher than that of HurtadoPonce et al. (1988) at 126.5 g. For *G. verrucosa* of both sources and *G. salicornia,* rupture forces were noted to be much lower than those reported by Hurtado-Ponce et al. (1988) at 266.0g and 127.33 g, respectively.

Rupture force of *Gelidiella acerosa* of Balaoan) was strongly affected by cohesiveness (r = 0.991) while *Gelidiella acerosa* of Sto. Tomas was moderately affected by its cohesiveness (r = 0.772). For *G. coronopofilia* of Balaoan, rupture force was moderately affected by cohesiveness (r = -0579) and sulfate content (r = 0.718) while *G. coronopofilia* of Sto. Tomas was strongly affected by cohesiveness (r = 0.991). For *G. verrucosa* of Balaoan, rupture force was moderately affected by cohesiveness (r = 0.746) and moderately affected by sulfate content (r = 0.862) while *G. verrucosa* of Sto. Tomas was strongly affected by cohesiveness (r = 0.997) and sulfate content (r = 0. 985). Rupture force of *G, eucheumoides* was moderately affected by cohesiveness (r = 0.667) and sulfate content (r = 0. 667). For *G. salicornia,* rupture force was strongly affected by sulfate content (r = 0.996).

Cohesiveness (g) of agar

Table 6. showed the values of cohesiveness of agar of agarophytes of two (2) sources. Significant differences existed among the values. However, the cohesiveness of agars of *Gelidiella acerosa* and *G. coronopifolia* were comparable but not comparable to *G. eucheumoides, G. salicornia* and *G. verrucosa*. *G. eucheumoides wa*s not comparable to *G. salicornia* and *G. verrucosa. G. salicornia* was likewise, not comparable to *G. verrucosa* . It implied that *Gelidiella acerosa* and *G. coronopifolia* produced best agar gels in terms of cohesiveness while *G. verrucosa,* the most inferior agar gel.

Table 6. Cohesiveness (g) of agar of agarophytes of two (2) sources.

Agarophytes	Source	
	Balaoan	Sto. Tomas
Gelidiella acerosa	$337.5^{a/a}$	$286.67^{a/b}$
Gracilaria coronopifolia	$394.23^{a/a}$	$200.67^{b/b}$
G. enheumoides	2408^{b}	*
G. salicornia	78.73^{c}	*
G. verrucosa	$32.47^{d/b}$	$86.77^{c/a}$

* no sample

Means (within a column and row) followed by a common letter are not significantly different at 0.05 level.

Cohesiveness (g) of agar of the Balaoan agarophytes ranged from 32.47g to 394.23g. *G. coronopifolia* recorded the highest value of cohesiveness while *G. verrucosa,* the lowest value. For Sto. Tomas agarophytes, cohesiveness of agar ranged from 86.77g to 286.67g. *Gelidiella acerosa* recorded the highest while *G. verrucasa,* the lowest value for cohesiveness.

Values of cohesiveness differed significantly. However, the cohesiveness of agar of *Gelidiella acerosa* was not comparable to G. *coronopifolia* and *G. verrucosa. G. coronopifilia,* was likewise, not comparable to *G. verrucosa.* It implied that *Gelidiella acerosa* produced the best agar gel in terms of cohesiveness followed by *G. coronopifolia* and *G. verrucosa,* with the most inferior agar gel. t-Test revealed that cohesiveness of agar gels of agarophytes common to both sources differed significantly. It implied that the cohesiveness of agars gels of *Gelidiella acerosa* and *G. coronopofilia* of Balaoan were better than of Sto. Tomas. However, cohesiveness of agar gels of *G. verrucosa* of Sto. Tomas was better than of Balaoan.

Cohesiveness of *Gelidiella acerosa* agar gels of Balaoan was weakly affected by sulfate content (r = 0.063) while that *Gelidiella acerosa* of Sto. Tomas was strongly affected by its sulfate content (r = -0.91). *G. coronopifolia* of Balaoan and Sto. Tomas was weakly affected by sulfate content (r = 0.22 and r = 0.063, respectively).

The cohesiveness of *G. verrucosa* agar gel of Balaoan was weakly affected by sulfate content (r = 0. 307) while *G. verrucosa* of Sto. Tomas was strongly affected by its sulfate content (r = 0.971). Cohesiveness of *G. eucheumoides* agar gel was strongly affected by its sulfate content (r = 1.0) while *G. salicornia* was weakly affected by sulfate content (r = 0.236).

Sulfate content (%) of agar

Table 7. showed the sulfate contents (%) of agar of agarophytes of two (2) sources. Sulfate contents (%) of agar of Balaoan agarophytes ranged from 1.73% to 12.67%. *G. eucheumoides recorded* the highest while *G. coronopifolia,* the lowest sulfate content. Result implied, however, that *G. coronopifolia* having the least sulfate content produced the best quality agar while *G. eucheumoides,* with the highest sulfate content produced the most inferior quality agar. Differences in sulfate contents of agar of Balaoan agarophytes were significant. However, further analysis revealed that the sulfate content of agar of *G. eucheumoides* being the highest, was not comparable to *G. verrucosa, G. salicornia, Gelidiella acerosa* and *G. coronopifolia.* However, sulfate contents of *G. salicornia, Gelidiella acero*sa and G. *coronopifolia* were comparable.

Table 7. Sulfate contents (%) of agar of agarophytes of two (2) sources

Agarophytes	Source	
	Balaoan	Sto. Tomas
Gelidiella acerosa	1.93[c]	1.20[c]
Gracilaria coronopifolia	1.73[c]	2.80[a]
G. eucheumoides	12.67[a]	*
G. salicornia	2.60[c]	*
G. verrucosa	7.12[b]	2.0[b]

**no sample*

Means (within a column and row) followed by a common letter are not significantly different at 0.05 level.

For the Sto. Tomas agarophytes, sulfate contents ranged from 1.20% to 2.80%. *G. coronopifolia* recorded the highest while *Gelidiella acerosa,* the lowest sulfate content. Results implied, however, that *Gelidiella acerosa* produced the highest quality agar while *G. coronopifolia,* the lowest quality agar in terms of sulfate content. Significant differences existed among the sulfate contents. However, the sulfate content of *G. coronopifolia* being the highest, was not comparable to *G. verrucosa. G. verrucosa* was likewise, not comparable to *Gelidiella acerosa.*

t-Test revealed the sulfate contents of agar of G. *coronopifolia* and G. *verrucosa* of both sources differed significantly but not for *Gelidiella acerosa.* It implied that the quality of agar of Balaoan was better than of Sto. Tomas while *G. verrucosa* agar of Sto. Tomas has a better quality than of Balaoan in terms of sulfate content. However, the quality of *Gelidiella acerosa* of both sources were comparable. Sulfate contents of agar recorded in this study by *Gelidiella acerosa* of both sources were observed to be lower than the value reported by Montaño et al. (1991) at 2.22%.

For *G. coronopofilia* of both sources, sulfate contents recorded were noted to be lower than those reported by Montano et al. (1991 from 4.23% to 5.64%. For *G, verrucosa* of Balaoan, the sulfate content was observed to be higher, however, the value for *G. verrucosa* of Sto. Tomas was observed to be within the values reported by Montano et al. (1991) from 1.58 % to 4.90%. The value of sulfate recorded for *G. eucheumoides* was much higher than those reported by Montaño et al. (1991) from 3.67 % to 3.92%.

Conclusions

Gelidiella acerosa and *Gracilaria coronopifolia* of Balaoan produced a comparable high quality agar in terms of yield, melting temperature, gel strength, rupture force, cohesiveness and sulfate content. Both agarophytes produced the strongest/hardest and most rigid gel. *Gelidiella acerosa* of Sto. Tomas produced significantly higher quality agar in terms of gel strength, rupture force and cohesiveness. Agar of Sto. Tomas agarophytes produced significantly lower quality in terms of gel strength, rupture force and cohesiveness compared to agarophytes of Balaoan. Agar produced are softer in quality. Relationships existed among the physicochemical properties ranged from weak to moderate to strong either negatively or positively. The following are the recommendations: to improve the yield of agar, studies on the effect of extraction methods and seasonality of agarophytes should be conducted; to further decrease the sulfate content of agar, studies on the effect of alkali concentration should be conducted since alkali treatment is one method of desulphation; application or use of agars produced from *Gracilaria* species and *Gelidiella acerosa* should be conducted to find their role in food and nonfood industries; Based on standard specifications (gel strength of 300-400 g/cm^2 or more), agars produced from *Gelidiella acerosa* and *G. coronopifolia* are recommended for bacteriological studies as culture medium. Agars having lower gel strengths should be used in food processing/preparation.

References

Armisen, R and F. Galatas, 1987. Production properties and uses of agar. In: D.J. Mc Hugh (ed). Production and Utilization of Products from Commercial Seaweeds. FAO Fisheries Technical Paper, Rome.

Chandrkrachang, S. and U. Chinadit, 1988. New approach in seaweed production and processing. INFOFISH International V.4, p. 22.

Food Chemicals Codex. 1981, 3rd ed. National Academy of Sciences, Inc: BocaRaton, Florida

Gomez, K. A. and A. A. Gomez. 1984. Statistical Procedures for Agricultural Research (2nd ed.) IRRI Book. Jonh Wiley and Sons. New York.

Hoyle, M. 1975. The Literature pertinent to the red algal genus *Gracilaria* from Hawaii. University Tech. Paper. 3:340 pp.

Hurtado-Ponce, A. And J. Umezaki . 1988. Physical properties of agar gel from *Gracilaria* Rhodophyta) of the Philippines. Bot. Mar. 31:121-174

Montano, N. E., L.T. David and G.C. Trono, Jr. 1991. Sources and Methods of Extraction of Agar for use in the food industry. A paper presented at the 30th Annual Convention of PAFT. Inc. PICC,

Montaño, N. E. and C.V. Pagba. 1996. Agar processing and characterization. Technology Manual Series. DOST-PCAMRD.

Santos, G. A. 1980. A manual for the processing of agar from. *Gracilaria.* ASEAN/8F/90/ Manual N. 5.

Veroy, R. L. and M.N. Montano. 1981, Spectrophotometric Methods and Sulfate Determination. SCS/GEN/81/29, Manila Phil.

Whyte, J.N.C. and J. R. Englar. 1980. Chemical composition & Quality of agar in the morphotypes of Gracilaria from British Columbia. Bot. Mar. 23:277- 283.