Extraction of Natural Fabric Dyes from Brown Seaweeds and their Immense Properties

Flora Gnanadhas
St Mary's College
Surendarnath Sundaramoorthy (surendarmech@gmail.com)
Sri Venkateswara College of Engineering and Technology https://orcid.org/0000-0003-4270-026X
Sowndharya Natarajan
St Mary's College
Mary Stephy Gnanamanickam
St Mary's College
Kassian T.T. Amesho
National Sun Yat-sen University College of Engineering
Bhisham Sharma
Chitkara University - Himachal Pradesh

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Abstract

Natural dyes had been identified for recent years but they cannot be replaced the synthetic dyes because of the requirement of knowledge about the usage of natural resources around us to produce massively. This study concentrated about the extraction and their dyeing properties of natural fabric dyes from different brown seaweeds (*Padina tetrastromatica, Sargassum tenerrimum* and *Turbinaria ornata*). Various experiments such as phytochemical analysis and FTIR analysis were performed to decide the phytochemicals that helps to dye the fabrics. There were various types of solvents (acetone, ethanol, methanol and water) used for extract the dye and mordants (CH_3 COOH, $FeSO_4$ and $NaHCO_3$) which helps to obtain different shades and excellent fastness properties. After dyes extracted by soxhlet extraction method, uncoated cotton fibres which underwent pre- mordanting process (2% mordant solution) were dyed. The dyed cotton fabrics showed shades of different colors based on the mordants and solvent used for dye extraction. Colour fastness assessments were provided the significant features of dyed fibres will have excellent dyeing properties or not. The results were indicated the aqueous and ethanol dye extracts have excellent fastness properties than acetone and methanol dye extracts. Faster properties did not control by the mordants used on cotton fibers.

Introduction

Dyes are widely used in a various industry such as food, textile, cosmetics, paper, paint etc. Dyes are a colorful organic compound that absorbs light in visible area and can firmly bind to substrates (fibers, food etc.) by chemical and physical bonding between the dye group and the group present on the substratum. Dyes, especially natural dyes, have been of unspoken importance in our lives for thousands of years, providing not only aesthetic satisfaction but also other useful applications. The global demands for natural dyes of great interest now a days because the general awareness of the therapeutic properties of natural dyes. Natural dyes are eco-friendly colorants that derived from biological sources (such as plants, animals) and minerals. A variety of natural dyes are obtained from different plant parts examples: roots, barks, leaves, fruit, seed, flower etc. that produce wide ranges of colour such as red, orange, yellow, green, the oldest and most widely used dye is indigo blue (*Indigofera tinctorum*), which has been used in India for the last four thousand years (Arora et al. 2017). Rather than indigo, there are so many plants and algae are have ability to wild range of color dyes due to the presents of categorized colorant compounds correspondingly photosynthetic pigments (chlorophylls, carotenes, xanthophylls, phycobilins (Phycocyanin and phycoerythrin), and fucoxanthin) and secondary metabolites (phenolic compounds) like anthroquinones, naphthoquinones, anthocyanin, usnic acid, tannins and vitamins (B compounds, C) (Osório et al. 2020).

Moreover, the sources used to produce natural dyes especially plants will not produce pollutant unlike the sources used in synthetic dyeing process. The colors of natural dyes consist of pigments and bioactive components that can be enhance the environment and do not have any harmful effect on the other environmental factor (Moldovan et al. 2016). At the beginning of the twentieth century, the cost of production of synthetic dyes was reduced and those reasons caused the reduction of natural dyes usages. Because of that, there is a drastic reduction of the usage of natural dyes was occurred. In this era, almost all colors which used everywhere in everything are chemically manufactured synthetic dyes. Because of their profitable nature such as more color production, low cost, brighter texture, more color fastness and easily mixed with product, used widely. Although these dyes have many beneficial uses, they also can cause side effects in our health and environment. Chemicals which is used in the production of synthetic dyes (Hg, Sn, Cr, Co, $NaCl_2$, Benzene) are toxic and carcinogenic factors that leads to form lethal mutation in any organisms in the environment. Wastewater from textile dye industries is released into drinking water resources, which can lead to contamination of surface water, ground water as well as land also (Khandare and Govindwar 2015**).** Recent years, researchers show more interest towards, the discovery of various and better natural dyes for replacing the current usage of synthetic dyes which have some lack of desirable fastness properties on textiles and lack of specific information on the chemistry of dyeing process and formulated dyeing methods **(Çalis et al. 2009).** This study aimed to share the possibilities for using seaweed as a source of natural dye and which are the conditions or processes will improve the effectiveness of different solvents and mordants.

Materials And Methods

Seaweeds collection

The three brown seaweeds were collected from Hare Island of Gulf of Mannar, Thoothukudi District (Jan- Mar 2021) **(**Table 1**).** The seaweeds were identified with a help of Phycology of Indica. Voucher deposited and preserved in Department of Botany Herbarium, St. Mary's College, Thoothukudi, Tamilnadu, India.

Table 1
List of three brown sea weeds

	Padina tetrastromatica Hauck	*Sargassum tenerrimum J.* Agardh	*Turbinaria ornata* (Turner) J. Agardh
Order	Dictyotales	Fucales	Fucales
Family	Dictyotaceae	Sargassaceae	Sargassaceae
Genus	*Padina*	*Sargassum*	*Turbinaria*
Species	P. *tetrastromatica*	S. *tenerrimum*	T. *ornate*

Selection of fibre

As a substrate for dyeing process, 100% cotton untreated threads with three different diameters (1.0mm, 2.10mm and 2.20 mm) were used for the experiment.

Selection of mordants

For differentiate the effect of acidic, alkali and metallic mordants in the dyeing, two percent (2%) of acetic acids, sodium bicarbonate and ferrous sulphate were used as mordants for each different dyeing process.

Dye extraction from brown seaweeds

Dye was obtained by the soxhlet extraction methods in the radio 1:20. Fresh seaweeds were dried and made into powder. For extraction, 10g of dry powdered samples were taken and loaded separately into the thimble. They were operated for 5 cycles with 200ml of 4 different solvents viz., acetone, ethanol, methanol and water with their respective boiling temperature. After this process, the extracts were collected in separate reagent bottles **(**Mona et al. 2019).

Estimation of concentration of dye in the extract

One gram of dye extracts were took in weighed beakers separately and placed into the boiling water bath till the extract became dry. After boiling, dry weight of extract was noted and concentration of dye was calculated.

Estimation of light absorption capacity

This estimation were contacted for identify the absorption of colour lights in selective wavelengths by each dye extracts of brown seaweeds. The dye solution was subjected to UV spectroscopy for absorption measurement at wavelength of 400–663 nm. The peaks present in the diagram were analyzed for which compound was absorbed that particular light wavelength.

Fourier Transform InfraRed (FT-IR) Spectrometric Analysis

FT-IR spectrometric analysis of three seaweed samples done by Instrumentation Centre, Ayya Nadar Janaki Ammal College, Sivakasi. The peaks were analyzed by the reference table for FT-IR spectrum. In this analysis, dye enhancing compound was found.

Preliminary phytochemical analysis

Preliminary phytochemical analysis of twelve different dyes extracted from three brown seaweeds **(**Geetha and Sumathy 2013**)**.

Quantitative analysis

In this analysis the number of primary metabolites present in the selected brown seaweeds was listed in Table 2.

Table 2
Quantitative Analysis of Primary metabolites

Primary metabolites	Method of used
Carbohydrate	(5)
Protein	(2)
Lipids	(8)
Crude fibres	(4)

Mordanting and dyeing process

Mordanting the fibres was done selectively before dyeing process (pre-mordanting process). The pre-soaked fibres were dipped in required mordanting solution (2%) (acetic acid, ferrous sulphate and sodium bicarbonate) for 20–30 min at 80˚C. Dyeing was done with natural dye at 85˚C for 40–60 min. after this process, the fibres were cold washed and dried under shade (Arora et al. 2017).

Colour Fastness analysis of dyed threads

Wash fastness of dyed threads

Wash fastness of dyed threads was tested by 3 different types of treatments namely, Cold water treatment, Hot water treatment, and Soap water treatment. In Cold water treatment the dyed threads were placed in cold water for five days and colour change was recorded for each day. In Hot water treatment, the dyed threads were placed 5 times in hot water bath for 30 minutes and the colour changes were recorded for each time. In Soap water treatment the dyed threads were placed in the soap water (5g/lit) for 5 days and the colour changes were recorded for each day. Colour change was recorded by 0–5 scales that means, 5- Excellent, 4- Good, 3- Moderate, 2- Poor, 1-Very Poor, and 0-No Efficient Results.

CIE- L* a* b* analysis

This assessment was conducted for measuring the colour of the dyed fibres. In this method, L * is defined as the lightness of the color, a * is the axis extending from red (positive) to green (negative), and b * is the axis extending from yellow (positive) to blue (negative). By these values, the dyed fibres dominant colours and shades will be detected easily. In this study, L* a* b* values were calculated with a help of android applications (color detector, color analysis and color grab).

Results

The dye solution was procured from the seaweed by solid-liquid extraction (Soxhlet) method using acetone, methanol, ethanol and water as solvent system (Arora et al. 2017).

Dye colour

Natural dyes were extracted from seaweeds with different solvents like acetone, ethanol, methanol and water; because of these different kinds of solvents, dyes were shown different colour. Dyes extracted by water was brown in colour other dyes gave green, greenish yellow and yellowish green shaded colours (Table 3).

Table 3
Colours of dyes extracted from brown seaweeds

S. No	Brown algae	Solvent used	Colors
1.	*Padina tetrastromatica*	Acetone	Green
		Ethanol	Green
		Methanol	Green
		Water	Brown
2.	*Sargassum tenerrimum*	Acetone	Greenish yellow
		Ethanol	Yellowish green
		Methanol	Green
		Water	Brown
3.	*Turbinaria ornate*	Acetone	Yellowish green
		Ethanol	Greenish yellow
		Methanol	Yellowish green
		Water	Brown

Dye concentration in seaweeds extracts

This analysis estimated the percentage of dyes dissolved in the seaweed extracts. According to our results, except acetone extracts other extracts extracted by ethanol, methanol and water retrieved more dyes (Table 4).

Table 4
Percentage of dye extracted from brown algae

Brown algae	Solvent used	Concentration of dye (%)
Padina tetrastromatica	Acetone	86.02
	Ethanol	98.77
	Methanol	99.1
	Water	98.26
Sargassum tenerrimum	Acetone	88.42
	Ethanol	98.33
	Methanol	99.9
	Water	98.31
Turbinaria ornata	Acetone	98.56
	Ethanol	99.72
	Methanol	97.67
	Water	98.8

Light absorption capacity of seaweeds dye extracts

The absorption spectrum of dye solution was obtained by UV spectroscopy at wavelength of 400–663 nm. UV- Vis spectrometry analysis helps to find out the intensity of dyes obtained from selected brown seaweeds (Fig. 1–3). The results showed that aqueous extracts of selected seaweeds were absorbed the blue (480nm) and orange (626nm) light highly. Ethanol extracts of *P. tetrastromatica* and *T. ornata* and the water extract of *S. tenerrimum* were absorbed the light from orange region at 626 nm. Ethanol extracts of three brown seaweeds were absorbed the red light at 645nm and 663nm. Absorption peaks were indicated the presence of flavonoids and chlorophyll. By correlating the data, γ-carotene (497 nm) and phycocyanins (590 nm and 614 nm) are effective in the aqueous extracts. Other dyes such as phycoerythrins (537 nm, 540 nm, 549 nm, 578 nm and 588 nm), phycocyanins (618 nm), β-carotene (478 nm) and chlorophyll β (627 nm) are active in the ethanol solvent.

FT-IR Spectrometry analysis

FT-IR spectral peaks were the indications of the functional groups of compounds present in the given absorption wavelength (cm-1). The composition of natural dyes was determined using FTIR spectroscopy, shown in Fig. 4–6. Since the different peaks found in FTIR studies on individual samples are identical, the strong peak in the spectrum Figs. 4 and 5 are seen at 1510.16. *P. tetrastromatica, S. tenerrimum* and *T. ornata* in Figs. 4 and 6, all dye samples with ethanol solvent showed sharp peaks due to the frequencies of aromatic stretching ν C-H and aliphatic ν C-H, respectively. In the wavenumber range of 1000–1500 cm-1, considerable isotropic properties (Fig. 4–6) have been seen in *P. tetrastromatica, S. tenerrimum and T. ornata* with low bending groups such as $-CH_2$, and $-CH_3$. Further investigations revealed that all the samples within the same region demonstrated the isotropic behavior with higher bending groups $-CH_2$, and $-CH_3$.

Preliminary phytochemical analysis

It was performed to analyze the presence of bioactive compounds (alkaloids, flavonoids, glycosides, phenols, quinine, saponins, steroids and tannins) in seaweeds dye extracts. In overall seaweed dye extracted by ethanol and methanol were recorded more positive results. Dyes were extracted by water had poor results in qualitative analysis. Among the four different extracts, ethanol extract of *T. ornata* showed the presence of maximum number (8) of compounds. Next to that, Methanol extracts of *S. tenerrimum* showed seven compounds (Table 5**).**

Table 5
Preliminary phytochemical analysis of different extracts of seaweeds

Seaweed	Solvent used	Alkaloids	Flavonoids	Glycosides	Phenols	Quinine	Saponins	Steroids	Tannins
Padina tetrastromatica	Acetone	+	-	-	+	+	+	-	+
	Ethanol	+	+	+	+	+	+	-	+
	Methanol	+	+	+	+	+	+	-	+
	Water	+	-	+	-	-	-	+	+
Sargassum tenerrimum	Acetone	-	-	+	+	+	+	-	+
	Ethanol	+	-	-	+	+	+	-	+
	Methanol	-	-	+	-	+	+	-	-
	Water	-	-	-	-	-	-	-	+
Turbinaria ornata	Acetone	-	-	+	+	+	+	-	-
	Ethanol	-	+	+	+	+	+	+	+
	Methanol	+	+	+	+	+	+	-	+
	Water	+	-	-	+	+	-	+	+

Quantitative analysis of primary metabolites

The results of these tests were shown in Figs. 7 and 8. When compared to other two seaweeds *S. tenerrimum* possessed more quantity of primary metabolites like carbohydrates (149 ± 1mg), protein (63.5 ± 1.26) and lipids (5.03 ± 0.26). Due complex constructions of thalli, *T. ornata* has more quantity of crude fibres (9.42%) than other two seaweeds.

Dyeing process

Dyed fibres

In (Fig. 9–12) shows the dyed uncoated cotton fibres (treated with and without mordants) with twelve different dyes extracted from three brown seaweeds. The shades of dyed fibres by usage of different mordant can be compared. In Fig. 10, the acetone extract of *T. ornata* was not fixed on the cotton fibres with and without application of mordants.

L*a*b* values

L*a*b* values for dyed cotton fibres with twelve different dye extracts from three brown seaweeds were figured in Fig. 13–16. The darkest shades obtained from the fibres treated with ferrous sulfate as a mordant. Cotton fibres with different diameters were obtained same colours. However, the lightest shades obtained from fibres treated with acetic acid and fibres which did not treat with water and these two samples produced almost similar shades in terms of lightness. Except aqueous seaweed dye extracts, other extracts have negative a* value that indicates the dyed fibres have a green shaded colour. The b* value of all extracts are positive that conclude that the yellow colour is shown in the dyed fibres.

Colour Fastness Properties

Washing fastness properties

The washing fastness properties of dyed cotton fibres recorded with a treatment of cold water, hot water and soap water are given in Tables 6–8. In cold water wash treatment, the dyed samples of aqueous dye extracts (all 3 seaweeds) have excellent fastness properties and rated between 4 and 5. The poor fastness properties rate was obtained by cotton fibres were dyed acetone (0) and methanol dye extracts (2–3). In hot water wash treatment, the fibres were dyed with ethanol dye extracts have good to excellent fastness properties and rated between 4 and 5. The poor fastness properties rate was obtained by cotton fibres were dyed acetone (0) and methanol dye extracts (0). In soap water wash treatment, all dyed cotton fibres shown the poor fastness properties and rated between 2 and 3. The fibres were dyed with aqueous dye extracts have better fastness properties and rated between 2 and 3. The poor fastness properties rate was obtained by cotton fibres were dyed acetone (0) and methanol dye extracts (0). There is no differentiation in fastness properties by mordant used and diameters of cotton fibres.

Table 6
Cold water wash treatment used for colour fastness assessment

Species name	Mordant name	AQ-E	AC-E	ET-E	ME-E
Padina tetrastromatica	NONE	5	0	4–5	2
Padina tetrastromatica	CH_3COOH	5	0	4–5	0
Padina tetrastromatica	$FeSO_4$	5	0	5	0
Padina tetrastromatica	$NaHCO_3$	5	0	4–5	0
Sargassum tenerrimum	NONE	5	0	4–5	1
Sargassum tenerrimum	CH_3COOH	5	0	4–5	2
Sargassum tenerrimum	$FeSO_4$	5	0	0	0
Sargassum tenerrimum	$NaHCO_3$	5	0	3–4	0
Turbinaria ornata	NONE	4–5	0	5	0
Turbinaria ornata	CH_3COOH	5	0	4–5	0
Turbinaria ornata	$FeSO_4$	4–5	0	3–4	3–4
Turbinaria ornata	$NaHCO_3$	4–5	0	0	4–5

Scales: 5- Excellent, 4-Good, 3- Moderate, 2- Poor, 1-Very Poor, 0-No Efficient Results. **Note**: AQ-E- aqueous dye extract, AC-E- acetone dye extract, ET-E- ethanol dye extract, ME-E- methanol dye extract.

Table 7
Hot water wash treatment used for colour fastness assessment

Species name	Mordant name	AQ-E	AC-E	ET-E	ME-E
Padina tetrastromatica	NONE	4–5	0	4	0
Padina tetrastromatica	CH_3COOH	4–5	0	4	0
Padina tetrastromatica	$FeSO_4$	5	1	4–5	1
Padina tetrastromatica	$NaHCO_3$	2–3	0	4	0
Sargassum tenerrimum	NONE	4–5	0	4–5	0
Sargassum tenerrimum	CH_3COOH	3–4	0	4–5	0
Sargassum tenerrimum	$FeSO_4$	5	0	2–3	0
Sargassum tenerrimum	$NaHCO_3$	2–3	0	3–4	0
Turbinaria ornata	NONE	1–2	0	4–5	0
Turbinaria ornata	CH_3COOH	1–2	0	2–3	0
Turbinaria ornata	$FeSO_4$	4–5	0	4–5	3
Turbinaria ornata	$NaHCO_3$	0	0	4–5	0

Scales: 5- Excellent, 4-Good, 3- Moderate, 2- Poor, 1-Very Poor, 0-No Efficient Results. **Note**: AQ-E- aqueous dye extract, AC-E- acetone dye extract, ET-E- ethanol dye extract, ME-E- methanol dye extract.

Table 8
Soap water wash treatment used for colour fastness assessment

Species name	Mordant name	AQ-E	AC-E	ET-E	ME-E
Padina tetrastromatica	NONE	2–3	0	1–2	0
Padina tetrastromatica	CH_3COOH	2–3	0	2–3	0
Padina tetrastromatica	$FeSO_4$	3–4	0	1	0
Padina tetrastromatica	$NaHCO_3$	3–4	0	0	0
Sargassum tenerrimum	NONE	4–5	0	2–3	0
Sargassum tenerrimum	CH_3COOH	2–3	0	2–3	0
Sargassum tenerrimum	$FeSO_4$	2–3	0	0	0
Sargassum tenerrimum	$NaHCO_3$	3–4	0	0	0
Turbinaria ornata	NONE	4–5	0	0	2
Turbinaria ornata	CH_3COOH	1–2	0	2	1
Turbinaria ornata	$FeSO_4$	2–3	0	0	0
Turbinaria ornata	$NaHCO_3$	2–3	0	0	0

Scales: 5- Excellent, 4-Good, 3- Moderate, 2- Poor, 1-Very Poor, 0-No Efficient Results. **Note**: AQ-E- aqueous dye extract, AC-E- acetone dye extract, ET-E- ethanol dye extract, ME-E- methanol dye extract.

Durability colour fastness of dyed fibres

Stored dyed fibres were shown the colour difference in storage period. Fibres which dyed with aqueous extracts (5) and ethanol extracts (4–5) have excellent dyeing properties. Other two dye extracts didn't have durability fastness (0). It may be caused by the evaporation property of solvent used for dye extraction as listed in Table 9.

Table 9
Durability colour fastness of dyed fibres which were stored

Species name	Mordant name	AQ-E	AC-E	ET-E	ME-E
Padina tetrastromatica	NONE	5	0	4–5	0
Padina tetrastromatica	CH_3COOH	5	0	5	0
Padina tetrastromatica	$FeSO_4$	5	0	4–5	0
Padina tetrastromatica	$NaHCO_3$	5	0	5	0
Sargassum tenerrimum	NONE	5	0	5	0
Sargassum tenerrimum	CH_3COOH	5	0	4–5	0
Sargassum tenerrimum	$FeSO_4$	5	0	5	0
Sargassum tenerrimum	$NaHCO_3$	5	0	4–5	0
Turbinaria ornata	NONE	5	0	5	0
Turbinaria ornata	CH_3COOH	5	0	5	0
Turbinaria ornata	$FeSO_4$	5	0	4–5	0
Turbinaria ornata	$NaHCO_3$	5	0	5	0

Scales: 5- Excellent, 4- Good, 3- Moderate, 2- Poor, 1-Very Poor, 0-No Efficient Results.

Note: AQ-E- aqueous dye extract, AC-E- acetone dye extract, ET-E- ethanol dye extract, ME-E- methanol dye extract.

Discussion

In this work, the three brown seaweeds (*P. tetrastromatica, S. tenerrimum* and *T. ornata*) were used as a source for obtain the natural dyes for fabrics. There are different types solvents (acetone, ethanol, methanol and water) and different types of mordants (acetic acid, ferrous sulphate and sodium bicarbonate) used for obtain different shades of dyes and excellent fastness properties in the uncoated cotton fibres with different diameters (1mm, 2.10mm and 2.20mm). After extraction of dyes by soxhlet extraction method, uncoated cotton fibres which underwent pre- mordanting process (2% mordant solution) were dyed. The dyed fabrics shown different shades of colours based on the mordants used and solvent which used for dye extraction. Colour fastness assessments were provided the significant features of dyed cotton fibres will have excellent dyeing properties or not. From this study, the results revealed the aqueous and ethanol dye extracts have an excellent fastness property than acetone and methanol dye extracts while Sodium hydroxide was found to be more efficient than acetic acid and distilled water for the extraction of natural colourants from Stoechospermum marginatum (Rani et al. 2020). Especially, the species *S. tenerrimum* dyes (aqueous and ethanol dyes) have more excellent properties than other two seaweeds. Fastness properties were not depended on the mordants which used on the cotton fibres. To know the phytochemicals which gave colour on fabrics by seaweeds, different experiments were done like preliminary phytochemical analysis (Qualitative analysis), Quantitative analysis of primary phytochemicals and FTIR analysis. It is confirmed that the secondary metabolites like flavonoids and tannins are the reason for colouring the fabrics. Light absorption capacity of seaweeds dye extracts confirms the presence of flavonoids, chlorophyll, γ carotene, Phycocyanins, Phycoerythrins, β carotene and Chlorophyll b. Hence all these pigments may responsible for colouring the fabrics.

Colors have been utilised throughout human history for painting and drawing, for women to enhance their own beauty and attractiveness, and for dyeing and colouring textiles like carpets, rugs, clothing, and leather using the roots, stems, barks, leaves, and flowers of various plants (Yusuf et al. 2017). The textile industry and living things are facing a serious dilemma as a result of the growing population and the crisis with synthetic dyes. Seaweed extract may be used as eco-friendly colouring to offer a potential solution and to solve these issues (Rani et al. 2020). Due to its bioactive qualities, such as antibacterial and antioxidant capabilities, as well as the fact that they are non-irritating to the skin, biodegradable, and biocompatible, seaweed is becoming increasingly popular for use in textile dyeing (Wang et al. 2005). Green algae generally used to create a natural colourant that was used on wool textiles (El-Khatib et al. 2016). It has also been stated that seaweeds are used in the process of dying textiles **(Janarthanan and Senthil 2017)**. The brown seaweed *Stoechospermum marginatum* has also been mentioned as having the potential to be used for sustainable fabric dyeing (Rani et al. 2020). These dyes can be used to remediate effluent from the textile and other sectors in addition to colouring clothes. *Codium decorticatum* was physiologically identified and employed as a sorbents for both cationic and anionic dyes from aqueous solutions (Oualid et al. 2020); likewise *Ulva lactuca* (El Nemr et al. 2006), *Spirogyra sp.* (Khataee et al. 2013), *Chlorella vulgaris* (Aksu and Tezer 2005), *Caulerpa stapeliiformis* (Aravindhan et al. 2007), *Systoceira stricta* (Salima et al. 2013) are used as biosorbents for efficient elimination of dyes from potable and contaminated waters. These are utilised for the extraction of natural colours in textiles and other fields of study since they are a rich source of bioactive compounds such chlorophyll, phycobiliproteins, carotenoids and sulphated polysaccharides (Rani et al. 2020).

Conclusions

Brown seaweeds have been used as biological source of the specialized polysaccharides align that have numerous commercial values like the thickener of paint, cosmetics, food, medicines etc. There are some seaweeds processing industries present in India for the extraction of alginate form brown seaweeds. If we commercialized these dyes, alginate processing industries can extract the dyes before extraction of alginates, therefore cultivation of brown seaweeds will increase the income of the seashore living peoples. It is time to take action to document these natural dyeing techniques for future applications. Otherwise, we will lose important information about the use of natural resources around us. In conclusion, there is an urgent need for proper collection, documentation, evaluation and characterization of dye-producing plants and algae and their dyes, as well as research to overcome the limitations of natural dyes.

Declarations

Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

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Author Contributions

All authors contributed to the study's conception and design. Material preparation, data collection and analysis were performed by [**Flora Gnanadas**], [**Sowndharya Natarajan**] and [**Mary Stephy Gnanamanickam**]. The first draft of the manuscript was written by [**Flora Gnanadhas]** and **[Surendarnath Sundaramoorthy]** and all authors commented on previous versions of the manuscript. Final review and editing were performed by [**Kassian T.T. Amesho**] and [**Bhisham Sharma**]. All authors read and approved the final manuscript.

Consent for publication

This manuscript has been read and approved by all the authors, and they have approved to submit and publish it in this journal.

Ethics approval

The research did not involve human or animal participants, and there was no release of harmful substance to the environment as a result of the study. The authors followed the rules for good scientific practice, as described in the author guidelines.

Consent to participate

Not applicable, as there were no human participants in the study.

Availability of data and materials

All the research data used in the study are available in the manuscript.

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Figures

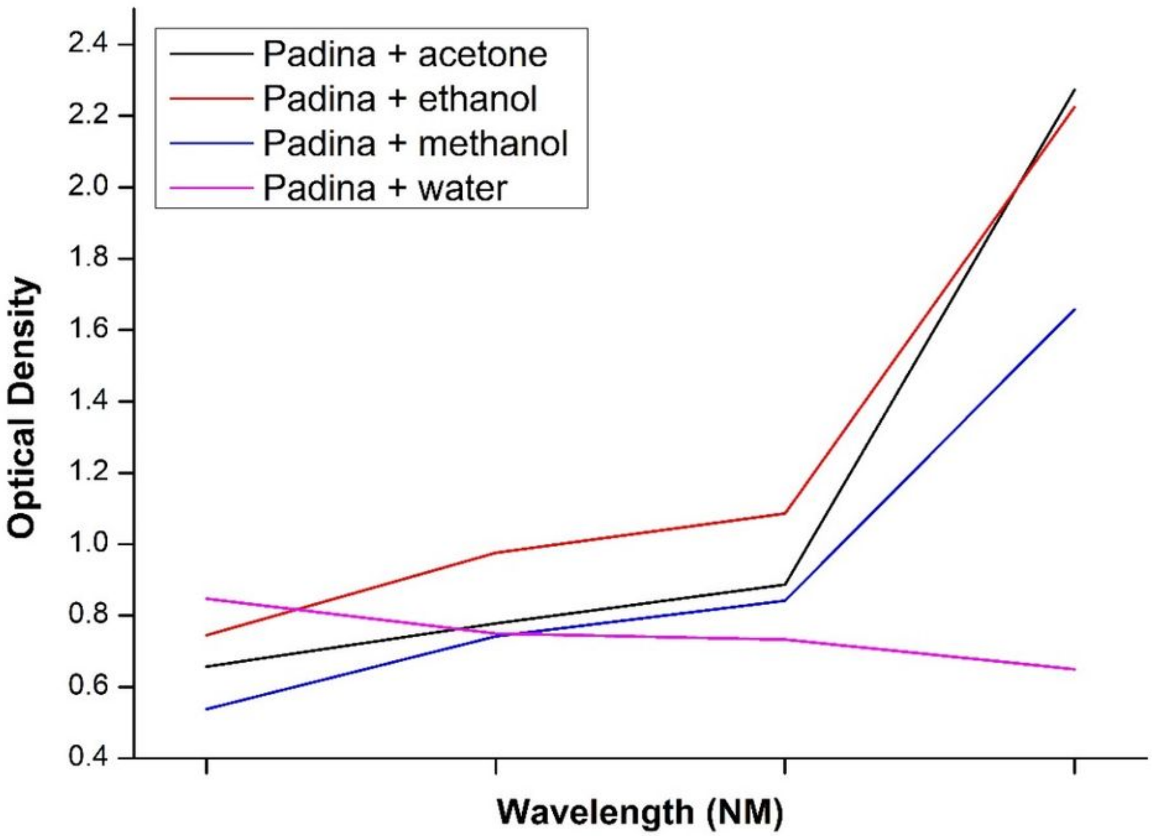

Figure 1

Estimation of light absorption capacity of Padina tetrastromatica dye extracts

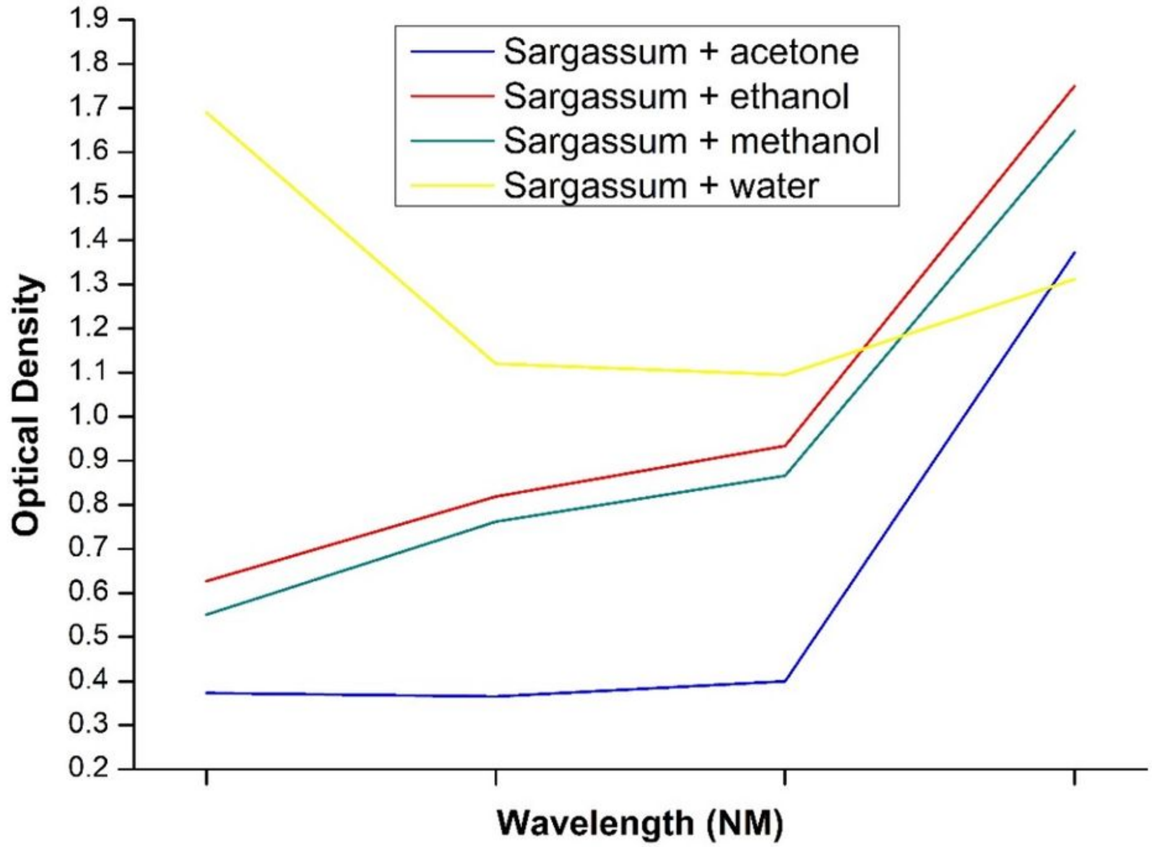

Figure 2

Estimation of light absorption capacity of Sargassum tenerrimum dye extracts

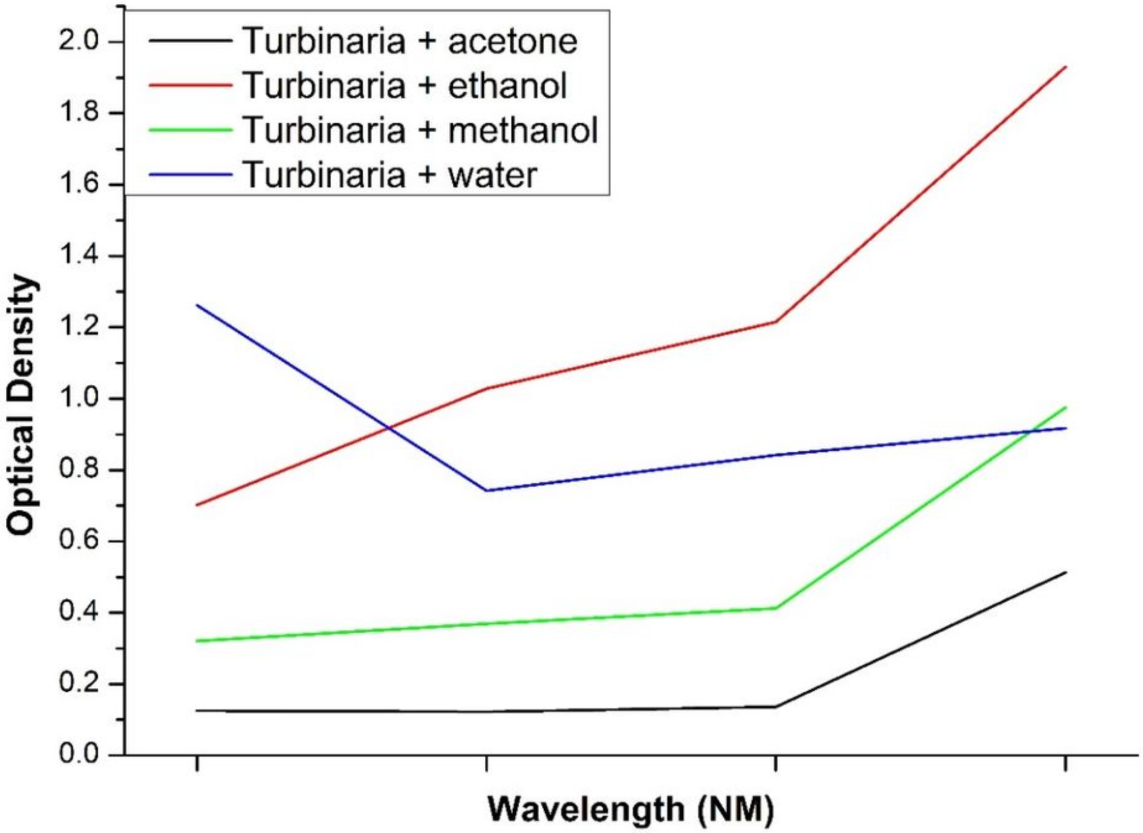

Figure 3

Estimation of light absorption capacity of Turbinaria ornata dye extracts.

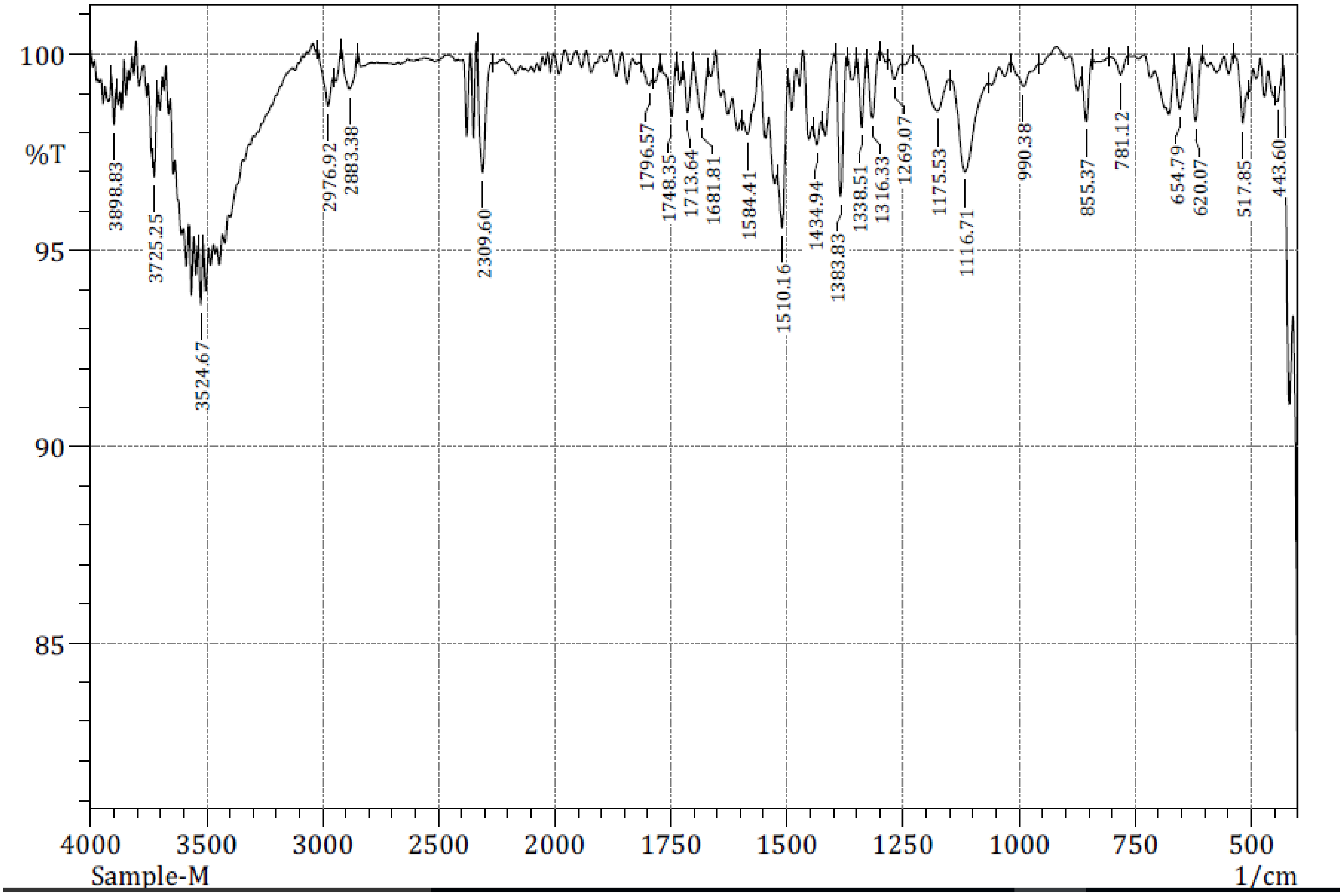

Figure 4

FTIR spectral peak values and functional groups obtained from Padina tetrastromatica

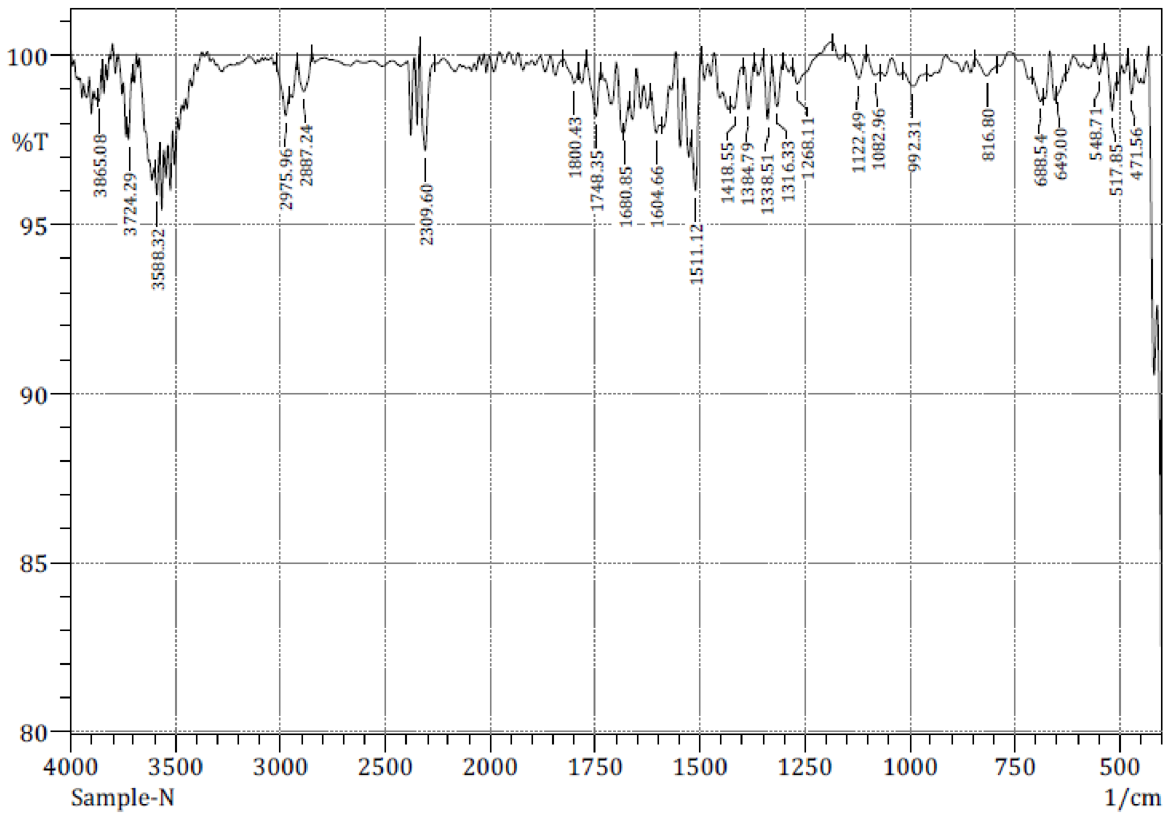

Figure 5

FTIR spectral peak values and functional groups obtained from Sargassum tenerrimum

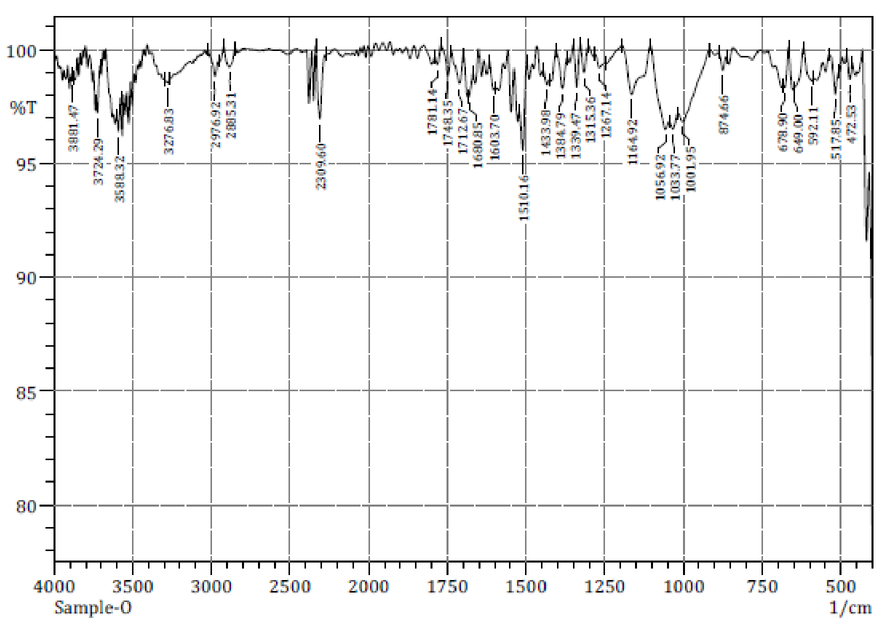

Figure 6

FTIR spectral peak values and functional groups obtained from Turbinaria ornata

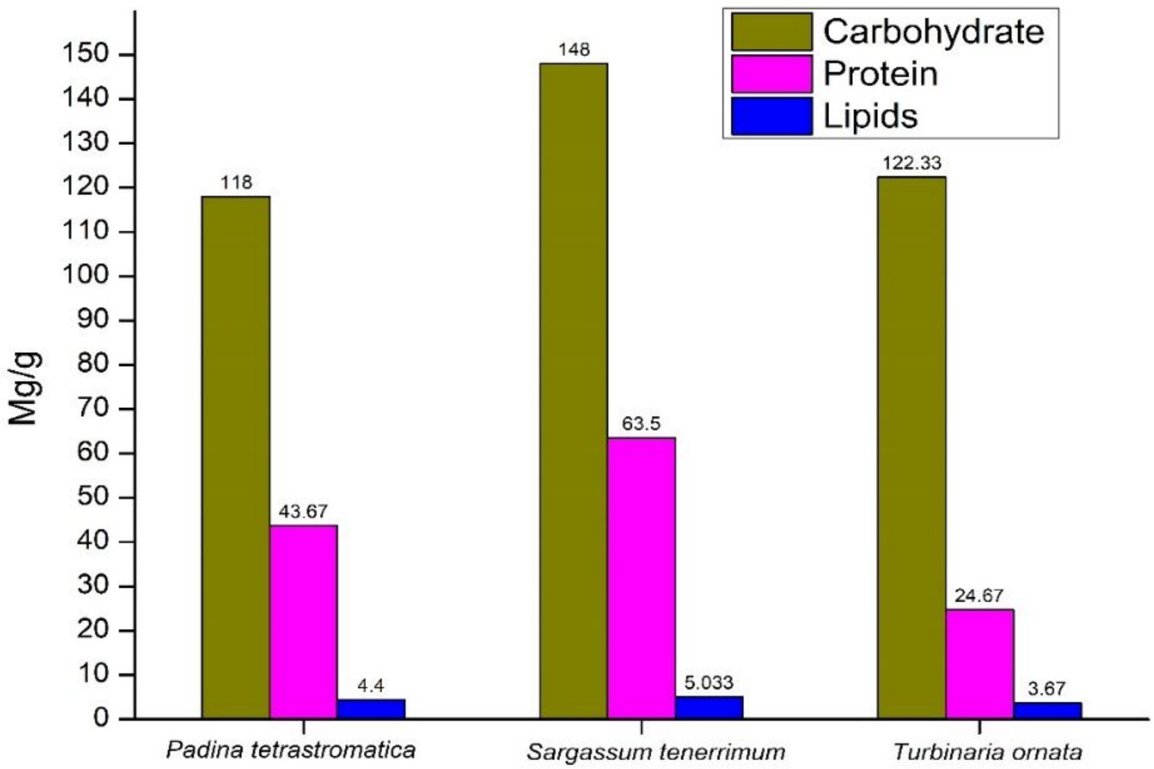

Figure 7

Estimation of primary metabolites in seaweeds collected from Hare Island

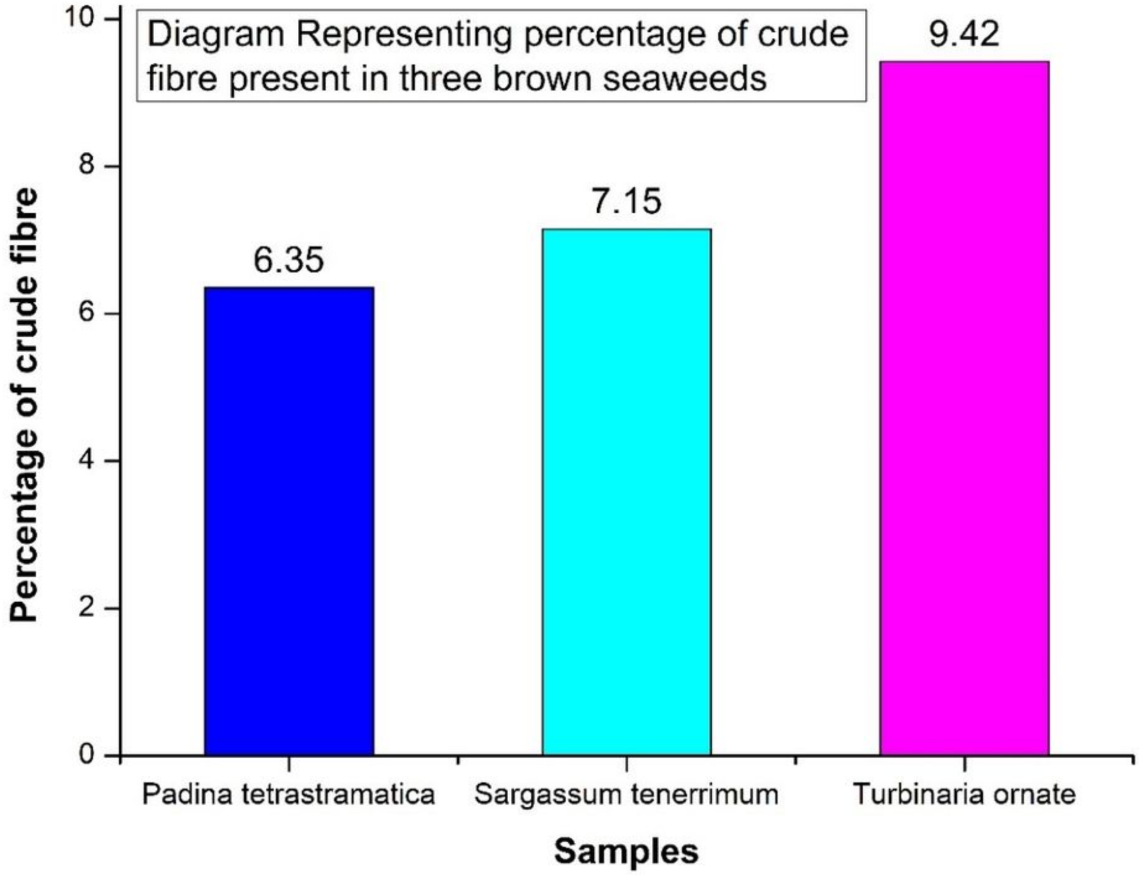

Figure 8

Diagrammatic representation of amount of crude fibre present in three brown seaweeds (in %)

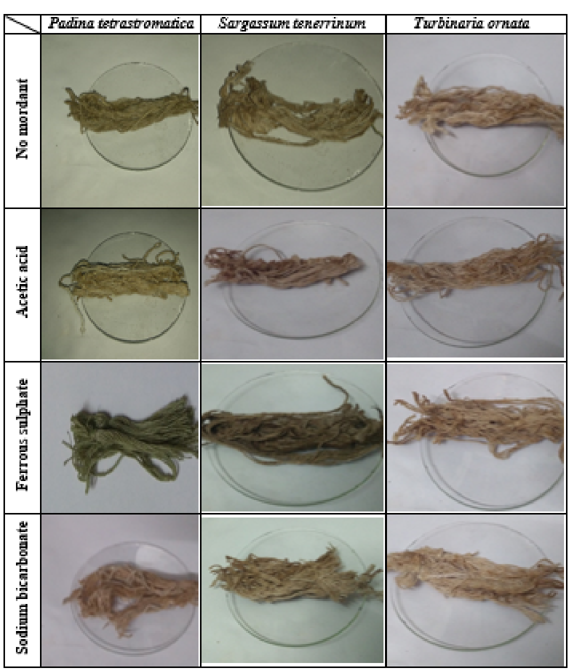

Figure 9

Colours intensity showed in uncoated cotton threads after the treated by aqueous extracts of brown seaweeds

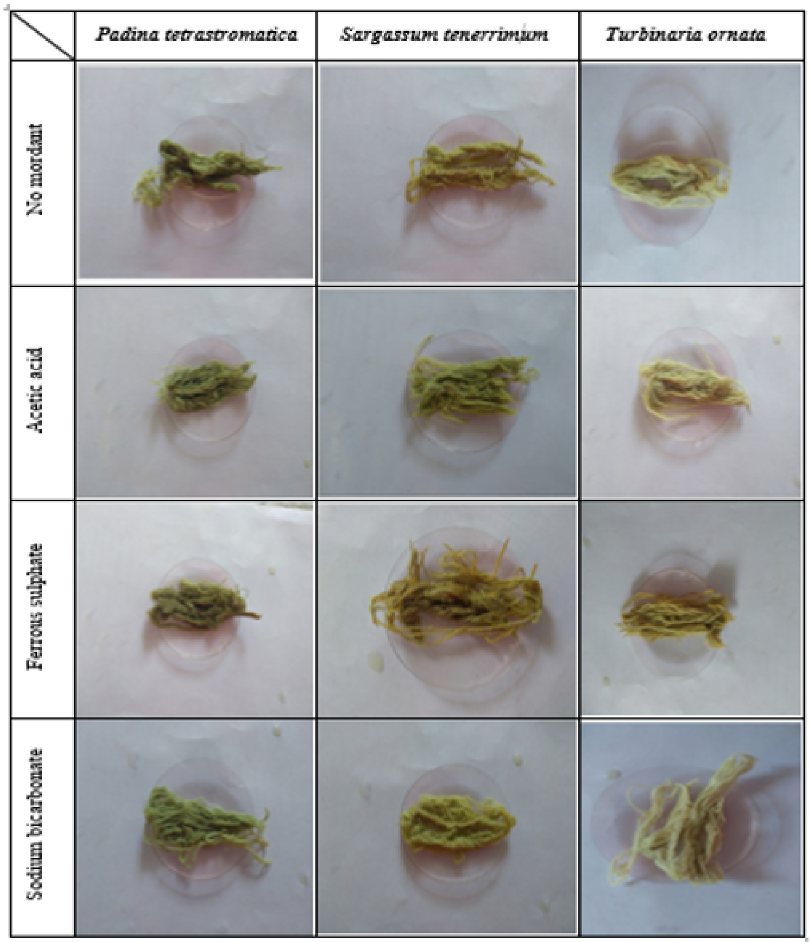

Figure 10

Colours intensity showed in uncoated cotton threads after the treated by acetone extracts of brown seaweeds

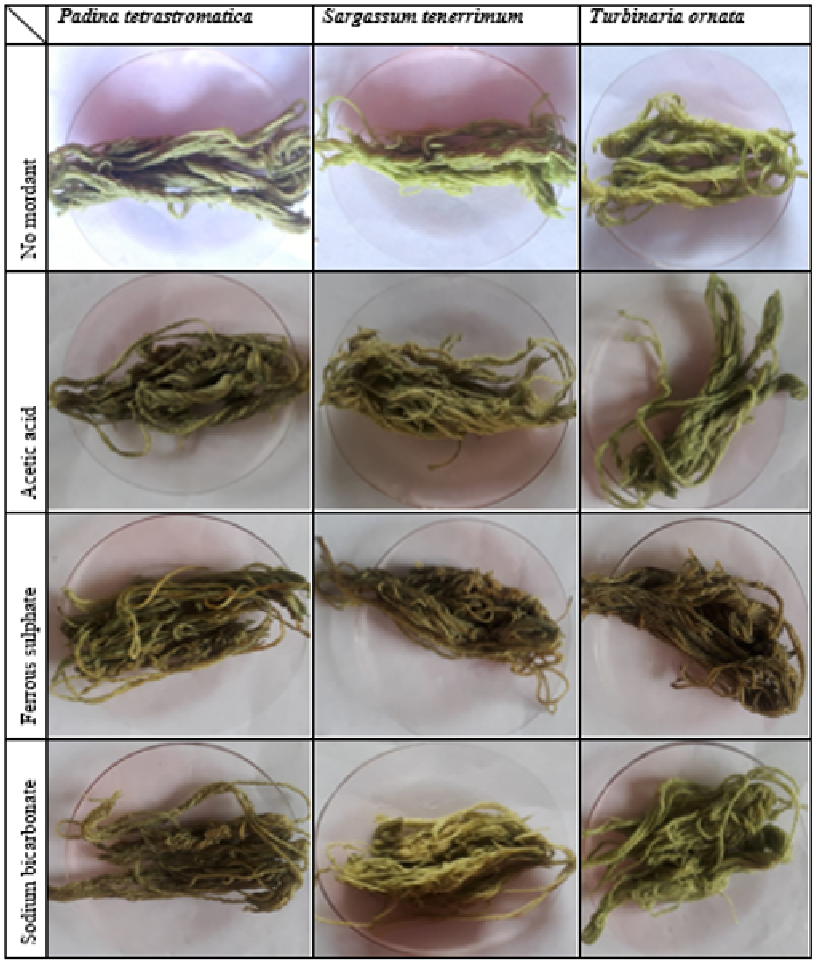

Figure 11

Colours intensity showed in uncoated cotton threads after the treated by ethanol extracts of brown seaweeds

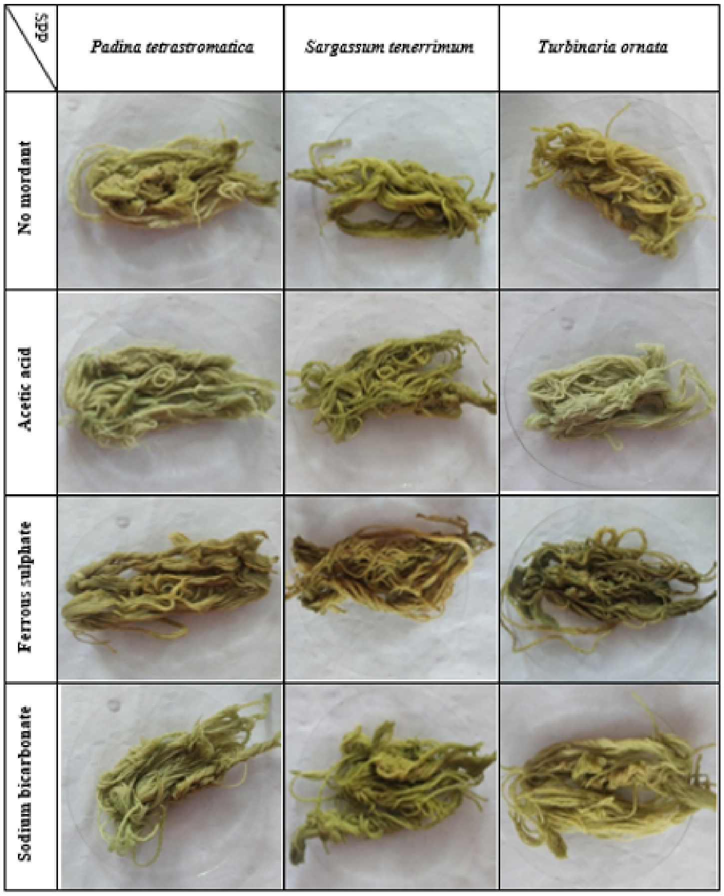

Figure 12

Colours intensity showed in uncoated cotton threads after the treated by methanol extracts of brown seaweeds

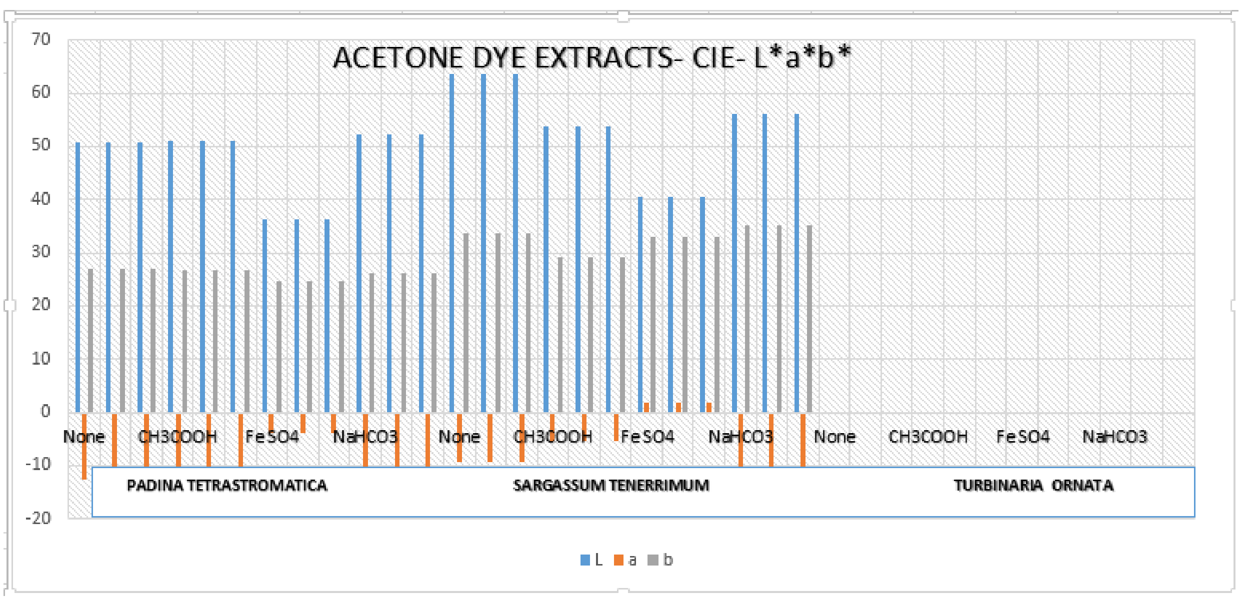

Figure 13

*L*a*b* values for dyed cotton fibres with seaweeds dye extracts extracted by acetone*

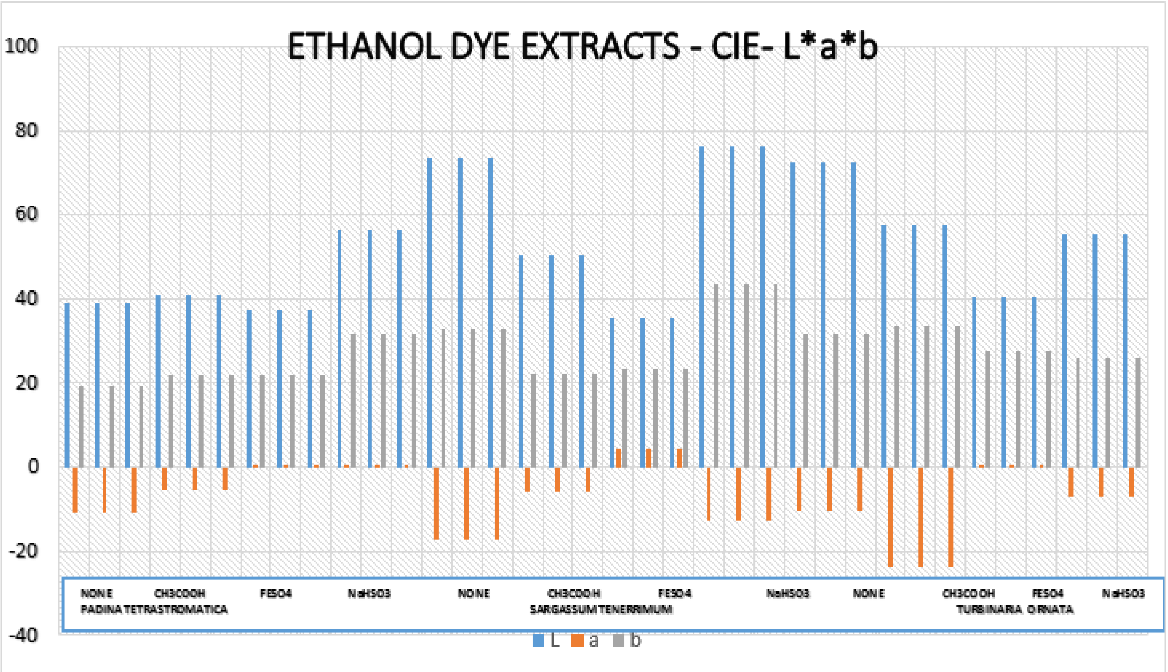

Figure 14

*L*a*b* values for dyed cotton fibres with seaweeds dye extracts extracted by ethanol*

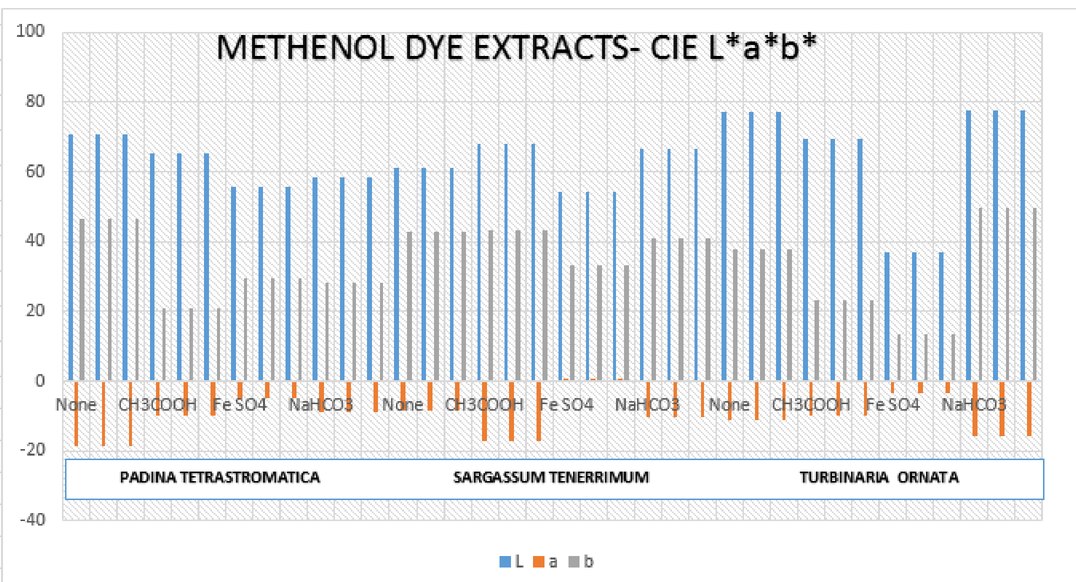

Figure 15

*L*a*b* values for dyed cotton fibres with seaweeds dye extracts extracted by methanol*

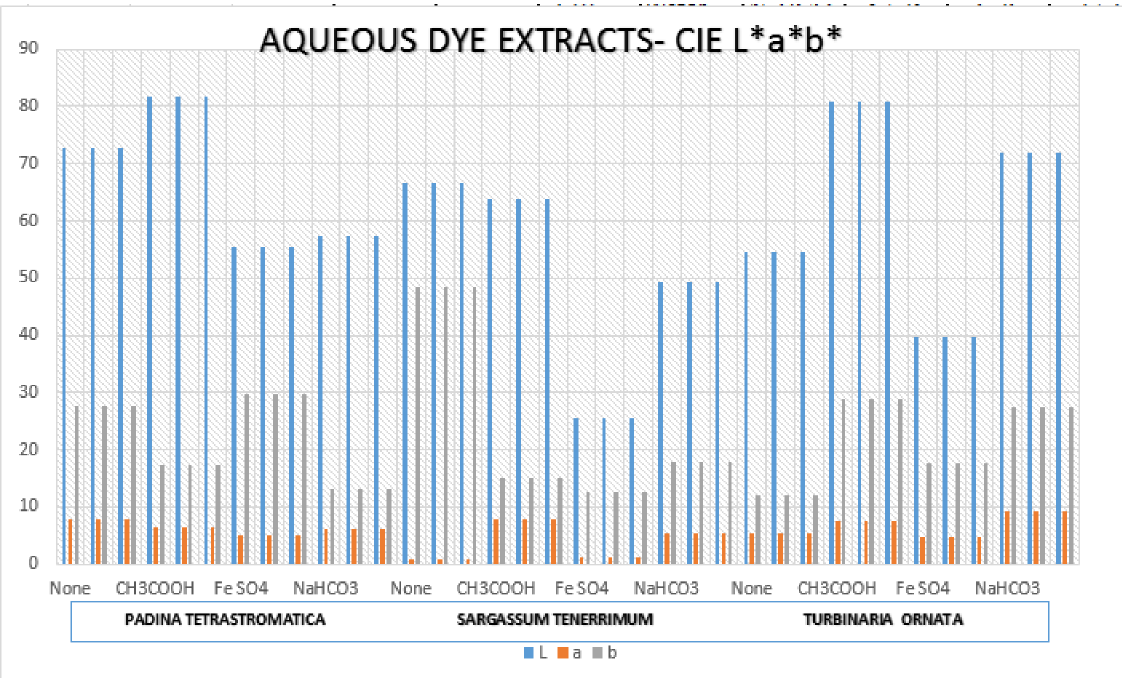

Figure 16

*L*a*b* values for dyed cotton fibres with seaweeds dye extracts extracted by water*

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