ORIGINAL ARTICLE

Pharmacological evaluation of anti-inflammatory potential and antispasmodic effect of aqueous extract from the brown seaweed, *Cystoseira compressa*

Évaluation pharmacologique du potentiel anti-inflammatoire et de l'effet antispasmodique de l'extrait aqueux de l'algue brune *Cystoseira compressa*

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Abstract

Introduction: Gastrointestinal (GI) pain is commonly treated with synthetic spasmolytic drugs, including anticholinergics, smooth muscle relaxants, calcium channel blockers, and opioid receptor modulators. However, these treatments often lead to undesirable side effects.

Aim: To evaluate the antispasmodic and anti-inflammatory potential of the aqueous extract from the brown seaweed Cystoseira compressa (Comp-AQ).

Methods: The antispasmodic activity of Comp-AQ was assessed in vitro using rat duode-num contractions induced by acetylcholine (A/Ch) and barium chloride ($BaCl_2$). The anti-inflammatory activity was evaluated in vivo using the carrageenan-induced paw edema model in rats. A phytochemical screening was performed to identify bioactive compounds, and antioxidant activity was assessed via the DPPH radical scavenging assay.

Results: Comp-AQ significantly and dose-dependently inhibited A/Ch- and $BaCl_2$-induced contractions (82.98 ± 1.5% and 84.06 ± 2.16%, respectively), with a relaxation-response profile similar to alverine, suggesting involvement of voltage-dependent calcium channels. In vivo, Comp-AQ reduced carrageenan-induced paw edema, reaching a maximal inhibition of 71.46% at 100 mg/kg after 3 hours. Phytochemical analysis revealed a high content of marine polyphenols and polysaccharides. The extract exhibited strong antioxidant activity with an IC_{50} of 30 ± 2.66 µg/mL.

Conclusion: The aqueous extract of Cystoseira compressa exhibits antispasmodic, anti-inflammatory, and antioxidant properties. Further structural characterization is needed to definitively identify the re-sponsible bioactive compounds and to confirm the hypothesis of synergistic effects.

Keywords: Seaweed – Cystoseira compressa – Antispasmodic activity – Anti-inflammatory activity – Marine polyphenols

Résumé

Introduction : Les douleurs gastro-intestinales (GI) sont fréquemment traitées à l'aide de médicaments spasmolytiques tels que les anticholinergiques, les relaxants du muscle lisse, les inhibiteurs des canaux calciques et les modulateurs des récepteurs opioïdes. Toutefois, ces traitements présentent souvent des effets indésirables notables.

Objectif : Évaluer le potentiel antispasmodique et anti-inflammatoire de l'extrait aqueux de l'algue brune Cystoseira compressa (Comp-AQ).

Méthodes : L'activité antispasmodique de Comp-AQ a été testée in vitro sur des contractions du duodénum de rat induites par l'acétylcholine (A/Ch) et le chlorure de baryum ($BaCl_2$). L'effet anti-inflammatoire a été évalué in vivo à l'aide du modèle d'œdème de la patte induit par la carragénine chez le rat. Une analyse phytochimique a été réalisée pour identifier les composés bioactifs et l'activité antioxydante.

Résultats : Comp-AQ a inhibé de manière dose-dépendante les contractions induites par A/Ch et $BaCl_2$, avec une efficacité comparable (82,98 ± 1,5 % et 84,06 ± 2,16 %, respectivement). Les courbes dose-réponse étaient similaires à celles de l'alvérine, suggérant une implication des canaux calciques voltage-dépendants. Comp-AQ a également réduit l'œdème de la patte avec un effet maximal à la 3ème heure (inhibition de 71,46 % à 100 mg/kg). L'extrait était riche en polyphénols et polysaccharides marins, avec une forte activité antioxydante (IC_{50} = 30 ± 2,66 µg/mL).

Conclusion : L'extrait aqueux de Cystoseira compressa présente des effets antispasmodiques, anti-inflammatoires et antioxydants intéressants. Des études de caractérisation structurale plus poussées sont nécessaires pour identifier formellement les composés bioactifs responsables et confirmer l'hypothèse d'une synergie.

Mots-clés : Algue marine – Cystoseira compressa – Activité antispasmodique – Activité anti-inflammatoire – Polyphénols marins

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Introduction

Gastrointestinal (GI) diseases significantly affect quality of life, work productivity, and daily activities, and they are associated with increased healthcare costs. The etiology of functional and motility disorders remains unclear; however, the most common symptoms include nausea, vomiting, bloating, abdominal pain, constipation, and diarrhea (1,2). The management of GI disorders primarily involves the use of smooth muscle relaxants, particularly antimuscarinic (anticholinergic) agents and calcium channel blockers. Although these treatments are generally well tolerated, anticholinergic drugs are associated with atropine-like adverse effects, including dry mouth, urinary retention, headache, nausea, and constipation (1).

Currently, the consumption of various seaweed species is particularly high in East Asian countries such as Japan, where the diet consists of approximately 66.5% brown algae, 33% red algae, and 5% green algae (3).

Brown seaweeds represent the second largest group of marine algae. The genus Cystoseira, belonging to the family Sargassaceae, contains a wide range of bioactive compounds exhibiting diverse biological activities and potential health benefits (4,5). Among the species of this genus, Cystoseira compressa is widely distributed in the Mediterranean Sea, the northeastern Atlantic Ocean, and the Black Sea (6). Recently, our research group reported several pharmacological properties of secondary metabolites isolated from marine algae collected along the Tunisian coast (7–12).

In a previous study investigating ethanol-induced gastric injury in a rat model, we demonstrated that polysaccharides isolated from Cystoseira compressa exhibited gastroprotective effects through the formation of a protective gel layer on the gastric mucosa (13). As a follow-up investigation, the present study evaluated the potential antispasmodic effect of the aqueous extract of Cystoseira compressa using isolated rat duodenum. To the best of our knowledge, the spasmolytic potential of brown seaweeds has not yet been thoroughly investigated. In addition, we assessed the anti-inflammatory activity of this aqueous extract using a validated rat model.

Methods

Chemicals and drugs

All chemicals, including Folin-Ciocalteu reagent, DPPH, diclofenac, Lysine acetylsalicylate (ASL), carrageenan, acetylcholine chloride (A/Ch), barium chloride ($BaCl_2$), trimebutine, atropine, and alverine, were purchased from Sigma-Aldrich (St. Louis, MO, USA). Drugs used for pharmacological studies were freshly prepared in normal saline (0.9% NaCl) on the day of the experiments.

Algal material and sample preparation

The brown seaweed Cystoseira compressa was harvested in July from the Mediterranean coast of Monastir, Tunisia. The dried algae were milled into a fine powder (<500 µm). The powder was packed in Whatman No. 1 filter paper bags and macerated in water at room temperature for 48 h with frequent agitation. The mixture was centrifuged (5,000 rpm, 10 min), and the supernatants were filtered, concentrated under vacuum, and lyophilized for 3 days. The crude aqueous extract (Comp-AQ) was stored at 4 °C.

Experimental animals and their housing

Wistar rats of both sexes (6-8 weeks old, 160–180 g) were obtained from the Pasteur Institute (Tunis, Tunisia). Animals were housed in polypropylene cages at 25 ± 2°C under a 12 h light/dark cycle, with free access to water and a standard pellet diet ad libitum. All procedures complied with the European Union guidelines for animal care (CCE Council 86/609).

Isolated rat duodenum preparation

Rats were fasted for 24 h with free access to water prior to the experiments. Following cervical dislocation, duodenum segments (1.5-2 cm) were rapidly excised, cleaned, and mounted vertically in a 20 mL organ bath containing Tyrode's solution at 37 °C, continuously gassed with 95% O_2 and 5% CO_2. Isotonic contractions were recorded using a Myograph transducer.

After a 30-minute equilibration period, cumulative concentration-response curves were generated for A/Ch and $BaCl_2$ to determine their EC_{50} and submaximal doses. To evaluate the spasmolytic effect, Comp-AQ (5-100 mg/mL), alverine (0.1-1 mg/mL), or atropine (0.1-5 µg/mL) were added to the bath two minutes prior to the application of a submaximal dose of A/Ch or a single dose of $BaCl_2$. The relaxant effect was expressed as the percentage reduction in maximal contraction compared to the control group.

Spasmolytic effect

The effect of the aqueous extract obtained from Cystoseira compressa (Comp-AQ) on tissues pre-contracted with Acetylcholine (A/Ch) and Barium chloride ($BaCl_2$) was evaluated. In the first series of the experiments, increasing concentrations of A/Ch and $BaCl_2$ were added to the organ bath cumulatively and dose-effect curves were established. Each duodenum specimen was used for only one concentration-response curve. Concentrations inducing half of maximal contraction response (EC50) values of both A/Ch and $BaCl_2$ were then calculated. Submaximal doses obtained from the correspondent curves will be used for the following series.

In the second experimental series, we investigate the effect of Comp-AQ (5-100 mg/mL) on the contractions induced by a submaximal dose of A/Ch on the rat duodenum. Experiments were also conducted in parallel by adding accumulative doses of two reference drugs: alverine (0,1-1 mg/mL) and atropine (0,1-5 µg/mL). Cumulative concentration-response curves were then generated. The aqueous extract or the pharmacological reference drug were tested on six segments of rat duodenum

from six different animals. Relaxation effect induced by each treatment was recorded and was expressed as the percentage reduction of contractions compared to the control group (i.e the maximal response obtained with A/Ch in the first cumulative concentration–response curve was considered as 100% response value).

In the last experimental series, tissues were pre-contracted with a single dose of $BaCl_2$. The aqueous extract (Comp-AQ, 5-100 mg/mL) was added to the preparations. Alverine (0.1-1 mg/mL) was used as antagonist. Relaxation effect induced by each treatment was recorded and was expressed as the percentage reduction of contractions compared to the control group (i.e the maximal response obtained with $BaCl_2$ in the first cumulative concentration–response curve was considered as 100% response value).

In both protocols, the concentration of the aqueous extract or the reference drug that reduces to 50% the maximal response of the spasmogenic agonist (EC50) were determined from individual concentration–response curves (14).

Carrageenan-induced rat paw edema model

To evaluate the anti-inflammatory effect of Comp-AQ, carrageenan-induced paw edema was conducted in male rats following the procedure adopted in our laboratory (Abdelhamid et al., 2018). For this study, Dexamethasone and Lysine acetylsalicylate (ASL) were used as standards at the doses of 1 mg/kg and 300 mg/kg, respectively. Thirty minutes after the administration of the sample Comp-AQ (50 and 100 mg/kg, ip) or the reference drugs, all rats received 0.05 mL of carrageenan (1% w/v, in saline solution) into the sub-plantar region of the left hind paw. The basal volume (V0) of the left hind paw of each animal was measured three times before the challenge by means of a Plethysmometer (model 750, Ugo Basile, Italy). The volume of both right and left hind paw was determined at 1, 2, 3, 4 and 5 h after carrageenan treatment (Vt).

The percentage of inhibition of paw edema for each group was calculated as follows:

Inhibition of edema(%) :

$$\frac{((Vt - V0)\ \text{Control group} - (Vt - V0)\ \text{Treated group})}{(Vt - V0)\ \text{Control group}} \times 100$$

Where

Vt : is the average volume for each group at the indicated t time, after carrageenan injection and

Vo : is the average volume obtained for each group at t0, before the beginning of the challenge

Phytochemical analysis

Analysis of proximate composition

The powdered algal material was analysed for moisture, lipid, proteins, ash and carbohydrates based on the AOAC processes (15). Moisture was determined by drying the replicates at 95°C until constant weight. The lipid content was measured by extracting in the Soxhlet a known weight of powdered material with petroleum.Protein content was estimated by using the Lowry method while the ash rate was estimated via weight difference before and after 5 h of incineration in a muffle furnace at 525°C. The total carbohydrates were obtained by difference (100 and the sum of protein, lipid, and ash contents) and expressed in percentage dry weight basis.

Estimation of total phenolic content (TPC)

Folin-ciocalteu based colorimetric method was used to evaluate the total phenolic content in the aqueous extract as previously described by Hermund et al. (16). The absorbance was measured at 725 nm in a UV/Vis spectrophotometer (Thermo Scientific™ Evolution 201). The assay was performed in triplicate and the resultant TPC was expressed as mg of Gallic acid equivalence (GAE) per g of dry algae.

DPPH radical scavenging activity assay

The DPPH radical scavenging potential of the aqueous extract was carried out according to the method described by Güner et al. and Abdelhamd et al. (17, 12). Free radical scavenging activity of quercetin and ascorbic acid as reference compound was also determined at the same concentrations of the extract. The radical scavenging activity was calculated by the given formula:

$$\text{DPPH scavenging effect (\%)} = \left(1 - \frac{\text{Abs sample - Abs sample blank}}{\text{Abs control}}\right) \times 100$$

The half-maximal inhibitory concentration (IC_{50}) values of Comp-AQ and the reference products were also calculated. The IC_{50} values were obtained using GraphPad Prism Version 8.3.0 (GraphPad Software, CA, USA).

Statistical analysis

Data was expressed as the mean ± standard error mean (SEM). The data of anti-spasmodic effect were analysed by ANOVA (one-way) followed by Dunnett's Multiple Comparison Test. The data of anti-inflammatory activity were analysed by ANOVA (one-way) followed by Tukey post-hoc test. A value of $p<0.05$ was considered significant. All the calculations, generated graphs, and statistical analysis likewise were carried out using GraphPad Prism Version 8.3.0 (GraphPad Software, CA, USA).

Results

Antispasmodic activity on rat isolated duodenum

Concentration-response curves showed that A/Ch and $BaCl_2$ induced dose-dependent contractions in the isolated rat duodenum (Fig. 1). The calculated EC_{50} values for A/Ch and $BaCl_2$ were 3.88 µg/mL and 3.18 mg/mL, respectively. Submaximal doses (inducing 80-90% of maximal contraction) were established at 5 µg/mL for A/Ch and 5 mg/mL for $BaCl_2$.

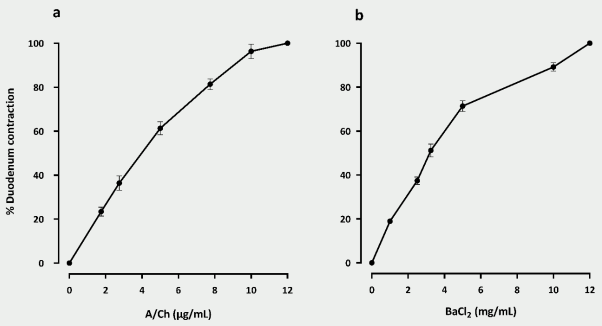


Figure 1. Graphs showing the cumulative concentration-response curves of the contractile effect induced by a) Acetylcholine (A/Ch) and b) Barium chloride (BaCl2) on the rat duodenum. Each point value represents the mean ± SEM of 6 preparations.

In A/Ch pre-contracted tissues, Comp-AQ (5-100 mg/mL) exerted a significant, dose-dependent relaxant effect, reaching a maximum inhibition (Emax) of 82.98 ± 1.5% at 100 mg/mL (Fig. 2c). For comparison, the reference antagonists atropine (5 µg/mL) and alverine (1 mg/mL) reduced maximal contraction by 97.48 ± 1.08% and 83.56 ± 0.73%, respectively (Fig. 2a, 2b).

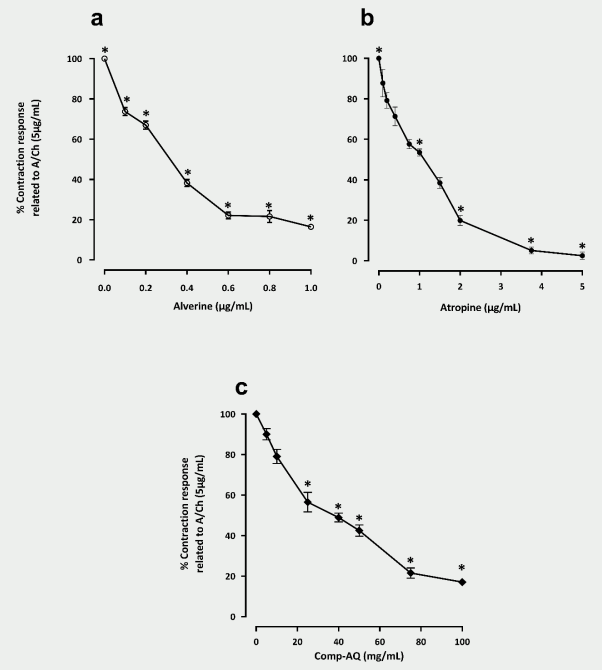


Figure 2. Cumulative concentration-response curves of the spasmolytic effect of a) atropine (0.1-5 µg/mL), b) alverine (0.1-1 mg/mL) and c) Cystoseira compressa aqueous extract (Comp-AQ, 5-100 mg/mL) on rat duodenum pre-contracted with Acetylcholine (A/Ch, 5 µg/mL). Each point represents the mean values ± SEM expressed in percent of maximal response of 6 segments. *p<0.05. One-way ANOVA followed by Dunnett's test versus vehicle group.

Similarly, Comp-AQ relaxed $BaCl_2$ pre-contracted duodenum in a concentration-dependent manner, achieving 84.06 ± 2.16% relaxation at 100 mg/mL (Fig. 3b). In this model, the reference drug alverine (1 mg/mL) exhibited an inhibition of 91.33 ± 0.87% (Fig. 3a).

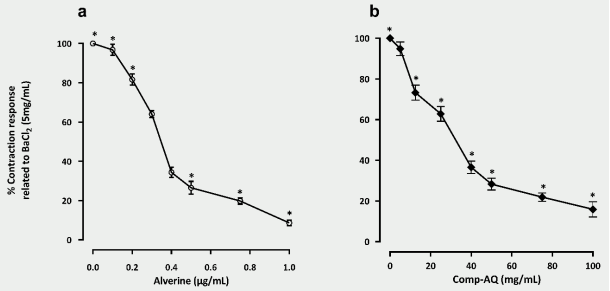


Figure 3. Cumulative concentration-response curves of the spasmolytic effect of a) alverine (0,1-1 mg/mL) and b) Cystoseira compressa aqueous extract (Comp-AQ, 5-100mg/mL) on rat duodenum pre-contracted with Barium chloride (BaCl2, 5 mg/mL). Each point represents the mean values ± SEM expressed in percent of maximal response of 6 segments. *p<0.05. One-way ANOVA followed by Dunnett's test versus vehicle group.

Anti-inflammatory activity on carrageenan-induced paw edema

Compared to the control group, Comp-AQ significantly and dose-dependently inhibited carrageenan-induced paw edema throughout the 5-hour observation period (Table 1). The maximal effect was observed at the 3rd hour, where Comp-AQ at 100 mg/kg reduced the edema volume by 71.46% ($p < 0.001$). This efficacy was comparable to the ASL-treated group, which showed a maximum reduction of 65.9% at the 3rd hour, while Dexamethasone exhibited its maximum effect (53.07%) during the early phase (1st hour).

Phytochemical analysis

The results of the total phenolic content (TPC) and the proximate composition (i.e moisture, ash, protein, lipid and carbohydrates) of Cystoseira compressa are summarized in table 2. TPC investigated in this study using Folin-Ciocalteu method was 71.18± 2.4 mg GAE/g dry algae. The moisture content of the fresh algae was found to be 66.6% while the ash content was 18.5%. Carbohydrate content (dry weight basis) was the major component in the proximate analysis of Cystoseira compressa. The carbohydrate content found in this study was 79,6 % followed by lipid (1,1%) and proteins (0.7%).

Measurement of DPPH scavenging capacity

Comp-AQ was screened for possible radical scavenging activity using DPPH in vitro model. The assay was performed against two well-known antioxidant products: quercetin and gallic acid and data was shown in Table 3. The aqueous extract exhibited a good scavenging properties by reducing 81.51 ± 3.36% of the DPPH radical at the concentration of 1 mg/mL.Lower IC50 values indicate a strong scavenging activity. The scavenging effect of Comp-AQ as well as reference standards on DPPH radical can be compared as follows: quercetin > gallic acid > Comp-AQ (Table 3).

Table 1. Effect of the aqueous extract obtained from *Cystoseira compressa* (Comp-AQ) on carrageenan-induced paw edema in rats, in comparison to the reference drugs (Dexamethasone and Lysine acetylsalicylate ASL).

Sample	Dose (mg/kg)	Edema (10^{-2} mL)			Edema inhibition (%)		
		1h	3h	5h	1h	3h	5h
Control	-	30.05±2.33	68.33±1.91	79.87±1.18	-	-	-
Reference drugs							
Dexamethasone	1	14.1±0.6**	48.12±0.75**	50.2±1.05**	53.07	29.57	37.14
ASL	300	11.93±1.53***	23.30±0.89***	36.27±1.12***	60.29	65.9	54.58
Comp-AQ	50	13.88±4.31**	29.13±6.1**	41.36±5.14***	53.8	57.36	48.21
	100	9.46±4.5***	19.5±2.92***	35.06±4.83***	68.51	71.46	57.35

Values are expressed as mean ± S.E.M; n = 8 animals.
**p < 0.01 and *** p<0.001 when compared with the control group (one-way ANOVA followed by Tukey post-hoc test).

Table 2. Total phenolic content (TPC) and proximate composition of the brown algae *Cystoseira compressa.*

Algae	Cystoseira compressa
TPC[a]	71.18±2.4
Moisture[b]	66.5
Ash[b]	18.5
Protein[c]	0.7
Lipids[c]	1.1
Total Carbohydrates[c]	79.6

[a] : mg GAE/ 100 g of the dry extract, [b] : % of fresh weight (Fw), [c]: % of dry weight (Dw)

Table 3. Comparison of DPPH scavenging properties of *Cystoseira compressa* aqueous extract and reference standards (quercetine and gallic acid).

Sample	Concentration (1 mg/mL)	IC_{50} (µg/mL)
Comp-AQ	81.51 ± 3.36 %	30 ± 2.66
Natural		
Quercetin	99.66 ± 1.5 %	17 ± 2
Gallic acid	95.33 ± 0.5 %	20 ± 2.25

Data are given as mean ± SD (n = 3).

Discussion

Brown algae species from Cystoseira genus are known to contain bioactive constituents with diverse therapeutic potentials. (12,13,17). In this study, the aqueous extract of C. compressa (Comp-AQ) was evaluated for its anti-spasmodic properties. A/Ch produced the contraction of rat duodenum via G-protein by the interaction with M3 muscarinic receptors; this will induce an increasing intracellular Ca2+ influx through voltage-dependent channels (1,18). It induces also the production of inositol triphosphate (IP3) which causes releasing of Ca2+ from sarcoplasmic reticulum (19). Alverine and atropine have been used as positive control to compare spasmolytic efficacy of the aqueous extract in this experiment. As shown in figure.2-c, Comp-AQ was able to inhibit A/Ch-induced contraction in a dose-dependent manner, with relaxation-response curves similar to the alverine behaviour. Alverine is a spasmolytic agent known to exert its effects primarily through modulation of voltage-dependent calcium (Ca^{2+}) channels (2). In contrast, atropine is an antimuscarinic agent that acts as a competitive antagonist by directly blocking acetylcholine (ACh) receptors. By inhibiting muscarinic receptor activation, atropine induces near-complete relaxation of smooth muscle tissue, even at low concentrations (1 µg/mL).

The spasmolytic effect of Comp-AQ was also studied on $BaCl_2$ pre-contracted rat duodenum (figure 3). $BaCl_2$ is a spasmogenic agent widely employed to investigate spasmolytic effect of natural products.

Numerous studies have indicated that different extracts or compounds obtained from Cystoseira genus possess interesting biological properties. In fact, it has been confirmed that Cytoseira genus has the potential to act as anti-inflammatory agent through both in vivo and in vitro models (7, 17, 20,21,22). However, a limitation of our in vivo study is the absence of specific biochemical measurements, such as the expression of pro-inflammatory cytokines, COX-2, or iNOS. Without these markers, a definitive mechanistic interpretation of the anti-inflammatory effect cannot be fully established.

Cystoseira compressa was submitted to phytochemical analysis in order to explain the spasmolytic effect as well as the anti-inflammatory activity of the aqueous extract. Data in Table 2 revealed the presence of high total phenolic compound. Polyphenol compounds include flavonoids (quecetine, catechin), gallic acid, phloroglucinol and phlorotannins.

While we hypothesize that the presence of these marine polyphenols and polysaccharides contributes to the observed activities, our global phytochemical analysis lacks advanced structural characterization (e.g., HPLC, LC-MS, NMR). Therefore, definitively attributing the pharmacological effects to specific active compounds, or confirming additive and synergistic effects among them, remains speculative at this stage.

Conclusion

The findings of this study suggest that the aqueous extract of Cystoseira compressa possesses relevant spasmolytic, anti-inflammatory, and antioxidant properties. These effects might be related to the direct relaxation of smooth muscle and the presence of bioactive marine

compounds. However, further detailed analytical studies (e.g., LC-MS, NMR) and biochemical assays are necessary to identify the specific molecules responsible and to elucidate the precise molecular mechanisms underlying these biological activities.

References

1. Wiya C, Saenphet K, Saenphet S, Buncharoen W. In vitro analysis of antispasmodic activity of ethanolic stem extracts of Uvaria rufa Blume and Anomianthus dulcis (Dunal) J. Sinclair on excised rat's ileum. Comparative Clinical Pathology. 2018; 27:295–299
2. Ranjbar S, Seyednejad SA, Nikfar S, et al. How can we develop better antispasmodics for irritable bowel syndrome? Expert Opinion on Drug Discovery. 2019; 14:549–562.
3. Tanna B, Mishra A. Nutraceutical potential of seaweed polysaccharides: structure, bioactivity, safety, and toxicity. Comprehensive Reviews in Food Science and Food Safety. 2019; 18:817–831
4. De Sousa CB, Gangadhar KN, Macridachis J, et al. Cystoseira algae (Fucaceae): update on their chemical entities and biological activities. Tetrahedron: Asymmetry. 2017; 28:1486–1505
5. Abdelhamid A, Lajili S, Elkaibi MA, et al. Optimized Extraction, Preliminary Characterization and Evaluation of the in Vitro Anticancer Activity of Phlorotannin Rich Fraction from the Brown Seaweed, Cystoseira sedoides. Journal of Aquatic Food Product Technology. 2019; 28:892–909
6. Oucif H, Miranda JM, Mehidi SA, et al. Effectiveness of a combined ethanol–aqueous extract of alga Cystoseira compressa for the quality enhancement of a chilled fatty fish species. European Food Research and Technology. 2018; 244:291–299
7. Ammar HH, Lajili S, Said RB, et al. Physico-chemical characterization and pharmacological evaluation of sulfated polysaccharides from three species of Mediterranean brown algae of the genus Cystoseira. DARU Journal of Pharmaceutical Sciences. 2015;23:1
8. Deghrigue M, Lajili S, Turki M, et al. Evaluation of anti-inflammatory, analgesic and gastroprotective activities of Eunicella singularis fractions using in vivo assays. Ann Med Biomed Sci. 2015; 1:23–8
9. Lajili S, Azouaou SA, Turki M, et al. Anti-inflammatory, analgesic activities and gastro-protective effects of the phenolic contents of the red alga, Laurencia obtusa. European Journal of Integrative Medicine. 2016a; 8:298–306
10. Lajili S, Deghrigue M, Bel Haj Amor H, et al. In vitro immunomodulatory activity and in vivo anti-inflammatory and analgesic potential with gastroprotective effect of the Mediterranean red alga Laurencia obtusa. Pharmaceutical biology. 2016b; 54:2486–2495
11. Lajili S, Deghrigue M, Abdelhamid A, et al. Anticancer activity of diterpenes and steroids from Eunicella singularis against two-and three dimensional breast cancer cell models. J Coast Life Med. 2017; 5:531–539
12. Abdelhamid A, Jouini M, Bel Haj Amor H, et al. Phytochemical Analysis and Evaluation of the Antioxidant, Anti-Inflammatory, and Antinociceptive Potential of Phlorotannin-Rich Fractions from Three Mediterranean Brown Seaweeds. Mar Biotechnol. 2018; 20:60–74.
13. Ammar HH, Lajili S, Sakly N, et al. Influence of the uronic acid composition on the gastroprotective activity of alginates from three different genus of Tunisian brown algae. Food chemistry. 2018; 239:165–171
14. Silva F.L. , Silva F.L. , da Silva J.L.V.,. Silva J.M., Marcolin L.S.A., Nouailhetas V. L.A , Yoshidaf M., Vendramini P.H. , Eberlin M.N., Barbosa-Filho J.M., Moreno Paulo R.H. Antispasmodic activity from Serjaniacaracasana fractions and their safety. Revista Brasileira de Farmacognosia. 2017; 27, 346–352,
15. Liu X, Zhang X, Rong YZ, Wu JH, Yang YJ, Wang ZW. Rapid determination of fat, protein and amino acid content in Coix seed using near-infrared spectroscopy. Food Analytical Method. 2015; 8(2): 334-342
16. Hermund DB, Heung SY, Thomsen BR, et al. Improving Oxidative Stability of Skin-Care Emulsions with Antioxidant Extracts from Brown Alga Fucus vesiculosus. Journal of the American Oil Chemists' Society. 2018; 95:1509–1520
17. Güner A, Köksal C, Erel ŞB, et al. Antimicrobial and antioxidant activities with acute toxicity, cytotoxicity and mutagenicity of Cystoseira compressa (Esper) Gerloff & Nizamuddin from the coast of Urla (Izmir, Turkey). Cytotechnology. 2015; 67:135–143
18. Ventura-Martínez R, Rodríguez R, González-Trujano ME, et al. Spasmogenic and spasmolytic activities of Agastache mexicana ssp. mexicana and A. mexicana ssp. xolocotziana methanolic extracts on the guinea pig ileum. Journal of ethnopharmacology. 2017; 196:58–65
19. Gharib Naseri M.K, Zarei M, Amiri O. Spasmolytic effect of Vitis vinifera leaf extract on rat colon. DARU Journal of Pharmaceutical Sciences. 2006;14:203–207
20. Mhadhebi L, Dellai A, Clary-Laroche A, et al. Anti-Inflammatory and Antiproliferative Activities of Organic Fractions from the Mediterranean Brown Seaweed, Cystoseira Compressa. Drug Development Research. 2012;73:82–89
21. Kosanić M, Ranković B, Stanojković T. Biological potential of marine macroalgae of the genus Cystoseira. Acta Biologica Hungarica. 2015;66:374–384
22. Celenk F. G, Sukatar A. Macroalgae of Izmir Gulf: Cystoseira barbata, Cystoseira compressa and Cystoseira crinita species have high α-glucosidase and moderate pancreatic lipase inhibition activities. Iran J PharmRes. 2020; 19(2): 391–402