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BIOTECNOLOGIA MARINHA E ALGAS: DA DIVULGAÇÃO CIENTÍFICA PARA AS REDES SOCIAIS AO MANUSCRITO PARA ACADEMIA

ARRAIAL DO CABO / RJ
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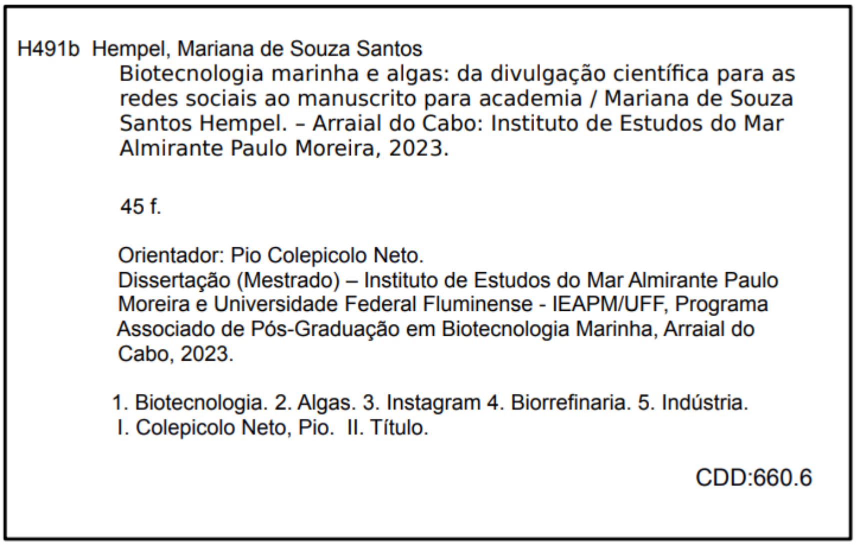

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RESUMO

As redes sociais aliadas a tecnologia tornaram o acesso à informação mais rápida, todavia não previu a legitimidade dessas informações. A divulgação científica em redes sociais surge como uma forma de apresentar o método científico de forma mais didática com linguagem simples, sem jargões, principalmente numa era pandêmica, de busca de resultados e entendimento científico. Diante disso, foi criado a página "algas pra que te quero" no Instagram, sobre Biotecnologia Marinha e o uso de algas nesse meio, para entender o impacto, dificuldades e alcance do tema ao público em geral. Com isso, o presente trabalho trouxe resultados positivos. Após um ano de página, nos insights (recurso da própria plataforma), foram alcançados, no total, 6.231 (seis mil duzentas e trinta e uma) visualizações, conquistados 215 seguidores, com uma média de interação de 60% de média. Os dados demonstram que houve uma significativa participação e interação dos usuários com o conteúdo fornecido. Para além dos números, essa página gerou entrevistas com pesquisadores da grande área que aborda, e a partir disso, gerou diversos frutos, entre eles, um manuscrito intitulado "Biorrefinaria de macroalgas para indústria cosmética: conceito básico, tecnologia verde e diretrizes de segurança", para responder as lacunas e indagações do espaço entre academia, indústria e sociedade.

Palavras-chaves: Biotecnologia, algas, Instagram, biorrefinaria, indústria

ABSTRACT

Social networks combined with technology allow to information faster but did not predict the legitimacy of this information. Scientific dissemination on social networks emerges as a way to present the scientific method in a more didactic way with simple language, without jargon, especially in a pandemic era, in search of results and scientific understanding. Given this, the page "Algas para que Te Quero" was created on Instagram, about Marine Biotechnology and the use of algae in this environment, to understand the impact, difficulties, and reach of the theme to the general public. With this, the present work brought positive results. After a year on the page, in the insights (resource of the platform itself), a total of 6,231 (six thousand, two hundred and thirty-one) views were achieved, and 215 followers were gained, with an average interaction of 60% of average. The data show that there was significant participation and interaction of users with the provided content. In addition to the numbers, this page generated interviews with researchers from the large area that it addresses, and from that, it generated several fruits, among them, a manuscript entitled "Biorefinery of macroalgae for the cosmetic industry: basic concept, green technology, and guidelines for security", to answer the gaps and questions of the space between academia, industry, and society.

Keywords: Biotechnology, algae, Instagram, biorefinery, industry

SUMÁRIO

1. CAPÍTULO 1

Divulgação Científica e redes sociais: o uso do Instagram como ferramenta para divulgação científica de Biotecnologia Marinha

2 INTRODUÇÃO

Desde o início dos tempos científicos, divulgar achados era essencial para manter o progresso das pesquisas, e isso se mantém nos dias atuais. O conceito de comunicação passa então para o âmbito da Ciência, e aliada a esse meio, ocorre atualmente, a inserção da tecnologia. Deve-se entender que no domínio desse tipo de divulgação existe a comunidade científica ou acadêmica, com sua linguagem específica de conhecimento, e os setores sociais que não estão nesse público, no caso, a sociedade no geral.

A tentativa de levar o conhecimento ao público, no Brasil, já é uma diretriz do Plano Nacional de Educação, o PNE, que com a promoção do princípio da gestão democrática da educação pública, incita e estimula o pesquisador a se tornar um comunicador. De acordo com Bueno (2009), a divulgação científica compreende a "[…] utilização de recursos, técnicas, processos e produtos (veículos ou canais) para a veiculação de informações científicas, tecnológicas ou associadas a inovações ao público leigo".

A divulgação entre os cientistas é realizada por meio de publicações em livros, artigos, periódicos eletrônicos e utiliza de jargão técnico, enquanto a linguagem para o público em geral sobre o conhecimento científico é feita pelas escolas por meio de livros e meios mais tradicionais. Os objetivos principais da divulgação científica consistem em: "educar, informar e cativar o público com as descobertas científicas" (TOSTES, 2006, p.74). Com a revolução tecnológica e a internet, isso mudou, principalmente durante a pandemia de COVID-19 (DE FREITAS *et al*., 2020).

Com a busca pela comunidade científica em alta, a tentativa de tentar entender o que se faz a partir do método científico, quais são os resultados, ou até o que motivou certas pesquisas, o público leigo passa a buscar, às vezes, erroneamente a informação. Exemplo dessa desinfomarção são as *fake news*, identificadas hoje como sintoma de um quadro amplo de desordens informacionais (COSTA *et al*., 2021). Deve-se entender que, o leigo diante de termos técnicos encara o assunto a ser entendido de modo complexo, criando uma barreira para o entendimento, quando o mesmo não deveria. Em função disso, tentou-se criar por meio da rede social que mais cresceu no mundo em número de usuários, que é o Instagram (SHELDON; BRYANT, 2016), uma página para decodificar ou recodificar o discurso especializado da Biotecnologia Marinha, por meio de metáforas, linguagens simples, ilustrações, entrevistas com os autores dos artigos citados durante uma explicação da pesquisa e até infográficos didáticos.

3 FUNDAMENTAÇÃO TEÓRICA

3.1 A comunicação científica e a sociedade

LUCKMANN (1995) abordou em seus estudos que o mundo em que vivemos e consideramos natural é elevado e sustentado por meio da comunicação, portanto, ele foi sucinto ao afirmar que a mudança ao longo do tempo em relação à comunicação não só afetou na evolução do discurso, como também na compreensão pública.

A comunicação entre a ciência e a sociedade foi, por muito tempo, unilateral. Uma vez que, os cientistas eram os detentores de conhecimento e colocados em um patamar de privilégios, responsáveis por transmitir esse conhecimento aos leigos. No passado, diversas tentativas de popularizar o conhecimento científico configuraram esta relação sem alterar essa concepção básica (GIBBONS *et. al*., 1997). Destaca-se entender também que existe a alfabetização científica, e isso inclui três elementos: conhecimento de fatos científicos básicos de livros didáticos, compreensão de métodos como raciocínio probabilístico e delineamento experimental, com apreciação dos resultados positivos da ciência e da tecnologia para a Ciência (BAUER et al., 2009), o que àquela época carecia de algum desses elementos.

A divulgação científica no Brasil e no mundo tem crescido significativamente nas últimas décadas, impulsionada pela *internet* e novas tecnologias (BUCCHI; TRENCH, 2008). Mas seu começo em território brasileiro, tal como se compreende hoje, foi tardio. A história tem início com a chegada da corte portuguesa em 1808. Onde os primeiros jornais como o Correio Braziliense (com edição na Inglaterra), A Gazeta do Rio de Janeiro e O Patriota já publicavam notícias e artigos relacionados à ciência (VALÉRIO, 2005). As ações de divulgação científica somente se intensificaram no Brasil, na segunda metade do século XIX, mas naquela época possuía cerca de 80% de sua população analfabeta, o que dificultava a disseminação do conhecimento (ALMEIDA, 2019).

Alguns questionamentos da sociedade, ao longo dos anos, surgiram durante o processo de entender a Ciência e até confiar em seus resultados. Em 1990, por exemplo, a Encefalopatia Espongiforme Bovina (EEB), o “mal da vaca louca”, ficou conhecida mundialmente após um surto na Grã-Bretanha durante os anos 1990, que provocou a suspensão do consumo de carne bovina no país e evidências de atitudes negativas em relação à Ciência, além do o debate sobre alimentos transgênicos (final dos anos 1990), o que suscitou em diversas pesquisas sociais que levaram ao diagnóstico de uma “crise de confiança” na Ciência, evidenciada no famoso relatório da Câmara dos Lordes de 2000 (BAUER *et al*. 2006). Todavia, essa confiança também já foi positiva em alguns momentos da história da sociedade, como o surgimento das novidades da Biotecnologia (BAUER *et al*., 2009).

A sociedade moderna, portanto, passou a possuir uma estreita relação com a Ciência, mas sobre esse relacionamento pairam ainda dúvidas, negaciosismos e fantasias sobre o modo como as informações científicas são produzidas. Um dos maiores enigmas é de que o cientista é um ser quase sobrenatural, enterrado em seu laboratório ou imerso em sua pesquisa, alheio ao interesse dos prazeres comuns como ir ao cinema, conviver em família, praticar esportes, fazer compras, entre outras atividades (MATEUS; GONÇALVES, 2017). Ao entender isso, o papel da Divulgação Científica passa a ser de desmistificar mitos e popularizar essa Ciência, por meio da estratégia de utilizar da Web para divulgar o conhecimento científico.

3.2 As redes sociais e o seu papel na divulgação científica

O uso das redes sociais como instrumento para disseminar o conhecimento gerado pela produção científica diminui a distância entre a pesquisa acadêmica e o público. Essa aproximação permitiu não somente um maior acesso as pesquisas, como se propôs justamente a construir pontes e diálogos entre ciência, mídia, cultura, indústria e sociedade. Logo, a forma como a sociedade entende a atividade científica e seus resultados torna-se um ponto crucial, assim como os tipos e canais de informação científica a que têm acesso (ALBAGLI, 1996).

A questão sobre o dilema do controle das tecnologias emergentes e das redes, (COLLINGRIDGE, 1980) diante de como proceder em condições de dúvidas e ignorância, também foram acompanhadas por preocupações crescentes sobre o valor público da ciência, a necessidade de demonstrar o 'impacto' da pesquisa (KEARNES & WEINROTH, 2011) e o lugar da participação pública tanto na definição de agendas de pesquisa quanto na modulação de trajetórias de pesquisa para fins socialmente desejáveis (JONES, 2008).

O modo rápido de navegar nas redes sociais potencializa o volume e a velocidade na difusão. Todavia, nesse momento deve-se refletir sobre a competência (crítica) da divulgação, das informações e da credibilidade dessas informações. Esse desenvolvimento acelerado de novas mídias, que é o caso das mídias sociais, trouxe mudanças significativas para o ambiente tecnológico da comunicação científica (ORBEN, 2020). A ciência divulgada nesses canais sociais alcança diferentes públicos e das mais diversas esferas da sociedade. As ações e interações desse público diverso nessas mídias são de diferentes maneiras e nos diferentes meios de produção científica divulgada (MENDES; MARICATO, 2020).

De acordo com HUNTER (2020), a evolução de imagens de vídeo, de realidade virtual, de realidade aumentada e de tecnologia de realidade mista criou um ambiente de informação visual intensiva para a comunicação científica e ampliou bastante a dimensão da interação entre especialistas e o público. Por meio disso, as mídias sociais conectaram pesquisadores que puderam construir conexões e realizar intercâmbios acadêmicos e obter novas ideias de pesquisa a partir delas (GRUZD; STAVES; WILK, 2012). Com essa relação, surge a necessidade de divulgar os resultados delas e da melhor maneira possível para o entendimento do público.

A partir disso, alguns países, como Reino Unido e Estados Unidos da América, oferecem diversos cursos de treinamento em comunicação científica, onde enfatizam as habilidades de comunicação técnica e orientam os cientistas a encontrarem suas oportunidades de comunicação. Exemplos desses programas são Alan Alda Center for Communicating Science e o Center for Public Engagement with Science and Technology na American Association for the Advancement of Science (XIA; HE; ZHOU, 2021).

Por meio desses exemplos, é observável que os pesquisadores têm se inserido nas mídias sociais, de forma a divulgar suas pesquisas e participar do diálogo com a sociedade. É crescente o uso dessas tecnologias, junto a pandemia de COVID-2019, por cientistas para divulgação de materiais em blogs científicos, postagens no Instagram, como um meio de ampliar até o networking com o LinkedIn ou com o ResearchGate, palestras em várias plataformas *on-line*, informações concisas em 280 caracteres no Twitter, vídeos no YouTube, são alguns exemplos entre muitos (MENDES; MARICATO, 2020).

Em se tratando de Instagram, as funções como as de compartilhamento facilitam alcançar uma maior trajetória e engajamento, com a possibilidade de comentar e curtir, que geram maior interação, bem como é possível ter um feedback quase imediato do impacto das postagens, essas métricas emergentes oferecem complementaridades às existentes (algoritmos já estabelecidos) e são inspiradas e lançam luz sobre os mecanismos da Ciência (WU *et al.* 2022). Como diz FERRARI (2010) “hoje a vida social passa pelo digital”. Em se tratando de ferramenta de *Marketing*, o Instagram é imbatível. A simplicidade e interação com os seguidores possibilita um contato mais próximo entre produtor de conteúdo e sua audiência. Além disso, existem ferramentas onde é possível mostrar um lado mais descontraído e informal do pesquisador, como exemplo o *Instagram Stories* (ALMEIDA, 2019).

Portanto, usar dessa rede para a divulgação científica não é simplesmente algo complementar, é uma continuidade do processo de publicar artigos e pesquisas, dessa forma a sociedade em geral tem acesso ao conhecimento e a ciência passa a ser difundida. A divulgação tem o papel de promover um acesso democrático à população para que assim ela possa embasar melhor suas decisões e ampliar o seu conhecimento (ALMEIDA, 2019).

Além de devolver o conhecimento produzido à sociedade com os recursos investidos na área por meio de seus impostos.

3.3 A divulgação científica de algas nas redes sociais

A biodiversidade marinha brasileira tem sido reconhecida mundialmente por ser fonte de compostos com propriedades biológicas diversas. Entre essas fontes, encontram-se as algas marinhas e seus diversos compostos bioativos. Essas afirmações anteriores são comuns no meio acadêmico, mas para a sociedade ainda pode ser mito ou pouco conhecida, uma vez que, nem todas as pessoas vão entender a importância do impacto das algas em suas vidas cotidianas.

Um estudo de DO, MISHRA E YANG (2021), por exemplo, avaliou se os tweets (disponíveis na rede social Twitter) que expressam sentimentos negativos em relação ao Lago Utah, nos EUA, estão relacionados à qualidade real da água do lago, e focaram nos parâmetros de qualidade da água percebíveis ao olho humano. Os parâmetros científicos foram turbidez, clorofila-a, profundidade do disco de Secchi, sólidos suspensos totais, contagem de células do fitoplâncton, biovolume de fitoplâncton, contagem de células de cianobactérias e biovolume de cianobactérias. Esses pesquisadores, então, chegaram a conclusão que a frequência de tweets falando sobre a qualidade da água do lago Utah com um sentimento negativo foi estatisticamente significativa e positivamente associada a vários parâmetros de qualidade da água, indicando, assim, que a exacerbação da qualidade da água aumenta o número de tweets negativos. A partir desse exemplo, entende-se que há uma forte relação da Ciência, mesmo que leiga por parte da sociedade, que contribuiu para que cientistas identificassem a saúde da água daquele lago e a periodicidade de ocorrências, de acordo com uma rede social.

Esses exemplos revelam novas e importantes abordagens, relativamente rápidas e econômicas de usar a mídia social para identificar problemas sociais e a partir disso, gerar respostas científicas. Todavia, o contrário também pode ocorrer. Pesquisas de MANNINO, BORFECCHIA E MICHELI (2021) utilizaram das atividades de ciência cidadã, envolvendo o público (por exemplo, turistas, pescadores, mergulhadores) na coleta de dados, como potencial para monitorar espécies de macroalgas não indígenas (NIS) e a magnitude do tráfego marítimo no Mar Mediterrâneo, que é um ponto crítico de invasões biológicas. Os resultados obtidos foram sistemas econômicos que podem ser ferramentas complementares úteis para o monitoramento de NIS, especialmente em áreas marinhas protegidas, que, apesar de seu papel fundamental na conservação da biodiversidade marinha, não são imunes à introdução de NIS. Portanto, a colaboração entre cientistas, mídias sociais e cidadãos pode ser uma metodologia científica útil para todos.

Com o surto da pandemia de Covid-19 e os seguintes bloqueios, a mudança de atividades educacionais e de trabalho para espaços virtuais foi acelerada (KLOOS *et al*., 2021). Plataformas de mídia social como o *Instagram* viram um aumento na sua adoção, com mais de 1 bilhão de usuários ativos mensais (INSTAGRAM, 2021) e sendo usado para divulgação científica em vários campos, uma vez que, muitas instituições científicas começaram a reconhecer a importância dessa divulgação. Pesquisadores como BROSSARD E SCHEUFELE (2013) citaram que:

> "sem pesquisa aplicada sobre a melhor forma de comunicar ciência online, corremos o risco de criar um futuro onde a dinâmica dos sistemas de comunicação online tem um impacto mais forte nas opiniões públicas sobre a ciência do que a pesquisa específica que nós, como cientistas, estamos tentando comunicar". (BROSSARD; SCHEUFELE, 2013, p. 41).

Logo, o uso do *Instagram* em uma breve pesquisa simples sobre algas disponibilizará resultados de diversas páginas e de diversos segmentos, como: Algas por elas @algasporelas, Algas do Brasil @algasdobrasil, Algas Praia Hotel @algaspraiahotel, Algas La Patrona @algaslapatronaseaweed, Algas Tech @algastech, Algii Algas Marinhas @algii_algas_marinhas, Moda Praia @algas_marinhas e mais algumas. A partir disso, é notável o tema alga, mas cada uma dessas citadas acima possui uma diferente abordagem, entretanto, apenas uma dessas supracitadas aborda a Alga e Divulgação Científica, que é a @algasporelas. Ao seguir em uma busca mais focada para esse tema voltado para divulgação, alguns outros aparecem, porém em número bem menor se comparado com o tema mais geral de Algas. Vale salientar que, a estética tem papel fundamental nestas páginas de estudo nas redes sociais, já que o *Instagram* é uma rede social para divulgação de imagens e vídeos. E as postagens seguem padrões de acordo com a categoria da página, com paletas de cor e organização das fotos, tudo a fim chamar atenção do público-alvo de acordo com preferências pessoais (LEAL et al., 2019).

4 OBJETIVOS

OBJETIVO GERAL

Fazer divulgação científica pelo *Instagram*, abordando o tema Biotecnologia Marinha e Algas, como forma de comunicar ao público em geral as pesquisas e o avanço da área.

OBJETIVOS ESPECÍFICOS

- Entender o impacto, dificuldades e alcance do tema, por meio das ferramentas fornecidas pela rede social escolhida;
- Promover postagens sobre temas associados as algas, de modo didático;
- Promover entrevistas com pesquisadores da área e do tema escolhido;
- Incentivar pesquisas na área, e com isso, divulgar grupos de pesquisas pelo Brasil;
- Compreender o que pode ser feito para melhorar cada vez mais esse canal de comunicação entre pesquisador e público em geral.

5 MATERIAL E MÉTODOS

5.1 Perfis de estudo no Instagram

Para o desenvolvimento deste trabalho, algumas contas no *Instagram* foram classificadas para serem analisadas, com perfis e objetivos distintos, a fim de compreender melhor o tipo de material divulgado, a partir da percepção, preferência pessoal e inspiração para a autora do presente trabalho.

O perfil @algasporelas tem fotos e vídeos voltados para divulgação científica e ensino de Botânica. Apresenta resumos de conteúdo didáticos, materiais de estudo, alguns vídeos curtos, divulgação de eventos, e foca em mulheres na ficologia (Figura 1). As imagens publicadas têm foco em elucidar conteúdos da área, parabenizar pesquisadoras, explicar curiosidades de modo divertido, sorteios e divulgação de oportunidades na área.

Figura 1 - Postagens na timeline do Instagram do perfil @algasporelas.

Fonte: Captura de tela feita pela autora

O perfil @redealgas é administrado por uma rede, a Rede Nacional em Biotecnologia de Macroalgas (REDEALGAS), de pesquisadores da área de algas e tem foco informativo e de divulgação. O perfil (Figura 2) conta com divulgações de eventos organizados por eles, atualizações de publicações na área e promove o conhecimento mais específico para o networking dos pesquisadores.

Figura 2 - Postagens na timeline do Instagram do perfil @redealgas.

Fonte: Captura de tela feita pela autora

A partir das análises desses perfis e de outros, foi pensado em como seriam os designs e marketings do perfil que seria criado na área escolhida para a divulgação desse estudo, e em como executar os próximos passos para a construção da divulgação científica desse estudo.

5.2 Design da página do Instagram

No dia 4 de junho de 2021 foi criada uma conta pública no aplicativo Instagram®, com ID de usuário nomeado @algaspraquetequero, com um desígnio feito para evidenciar algumas informações importantes na área da Biotecnologia Marinha voltada para Algas. Foi apresentado a logomarca (Figura 3) associando a figura da alga, sendo assim, possível identificar o perfil nas redes sociais e suas atividades.

Figura 3 - Logomarca da página criada no Instagram para divulgação

Fonte: Acervo pessoal

5.3 Abordagem das postagens no Instagram

Cada postagem era feita por tema, seguida de imagens, infográficos e textos. A partir do tema escolhido, estudos de artigos eram feitos e um *highlight* breve era colocado com imagens e gráficos, seguidos logo abaixo de um breve texto numa linguagem simples e conectada a realidade dos que navegam pela rede social (Figura 4). O foco era atingir um público mais amplo e fornecer impulsos para que um público leigo se tornasse curioso e aprendesse mais sobre pesquisa de algas e ciência, no geral. Portanto, o objetivo não era uma educação sobre Biotecnologia Marinha e Algas de forma completa, mas o fornecimento regular de percepções informativas e pessoais no campo, a fim de criar uma compreensão mais ampla do assunto e combater mitos, falácias e equívocos.

Figura 4 - Postagens na timeline do Instagram do perfil @algaspraquetequero.

Algas no combate aos vírus

Vários estudos na literatura têm demonstrado o grande potencial das algas e produtos naturais marinhos contra vírus, bactérias e fungos

herpes tipo 1 humano, vírus da imunodeficiência humana (HIV) e dengue

Onde elas estão sendo aplicadas?

Dictyota friabilis

um composto isolado dela inibiu a enzima transcriptase reversa do HIV-1 (Cirne-Santos *et al.* 2006)

Onde elas estão sendo aplicadas?

Eisenia aborea

Composto isolado dela mostrou potencial atividade antiviral contra ZIKV (Cirne-Santos *et al.* 2019)

Onde elas estão sendo aplicadas?

Dictyota pfaffii e *D. menstrualis*

Compostos isolados delas mostraram inibição de eventos iniciais durante a replicação de HSV-1(herpes simplex tipo1) (Abrantes *et al.*, 2009)

Curtiu? Já sabe, né? Compartilha, salva, envia pra os friends...
Algas, pra que te quero? Antiviral é um uso!

algaspraquetequero Olá! Hoje vamos falar sobre a importância do papel das algas nos medicamentos antivirais e onde está o Brasil nisso ☺.

As algas têm em sua composição metabólitos secundários. (Esses metabólitos secundários produzidos pelas algas têm como objetivo principal a proteção a estresses abióticos - luz, temperatura, vento, radiação solar e por aí vai - e bióticos -seres produtores, consumidores e decompositores, além de possuírem valores nutricionais e farmacológicos importantes na nutrição humana, servindo de aditivos aromáticos e corantes, sabe? 🤔).

Ao serem isolados por processos químicos (uma infinidade mesmo), essas substâncias são testadas em diferentes áreas, como nesse caso de hoje, antivirais.

Fonte: Captura de tela realizada pela autora

Após as postagens sobre o tema, pesquisadores e especialistas no assunto eram convidadas a uma entrevista (Figura 5), levada de modo a ser uma conversa informal, sobre o conhecimento que foi escolhido, e assim, viabilizar o canal na comunidade acadêmica e na sociedade. A partir disso, as pessoas podiam comentar, curtir e compartilhar esse assunto, e buscar mais "direto da fonte", que era o entrevistado.

Figura 5 - Postagens de entrevista na timeline do Instagram do perfil @algaspraquetequero.

algaspraquetequero Entrevista com a prof. Dra. Izabel Paixão

Oi, gente! Vocês lembram sobre eu ter dito que iria conversar com as fontes, os autores, no estilo globo repórter 😊? Então, no post anterior, foi falado do grupo de pesquisa brasileiro que atua na área de vírus e algas desde 1996, e um dos integrantes é a professora Doutora Izabel Christina Nunes de Palmer Paixão.

A Izabel atualmente é Diretora do Instituto de Biologia da UFF, Professora Titular do Departamento de Biologia Celular e Molecular-GCM-UFF e chefe do Laboratório de Virologia Molecular e Biotecnologia Marinha. Em 1990, criou o Laboratório de avaliação de atividade citotóxica e antiviral de substâncias naturais e sintéticas, situado no Instituto de Biologia-UFF, no Departamento de Biologia Celular e Molecular. Tem experiência

Fonte: Captura de tela feita pela autora

5.4 Alcance das postagens

Para a análise dos *posts* compartilhados os critérios de avaliação estabelecidos foram as métricas disponibilizadas pelo próprio Instagram®: número de seguidores conquistados para o perfil, número de compartilhamentos, salvamentos, curtidas, visualizações dos *posts* criados, Instagram TV, conhecido como IGTV, que é uma plataforma do Instagram voltada exclusivamente para vídeos, *reels*, uma ferramenta também em formato de vídeo e nesse só é possível gravar um vídeo de até 90 segundos, *stories* com a possibilidade de publicar fotos ou vídeos que ficam acessíveis por até 24 horas, e aumentam a interação entre seguidores, dados demográficos, distribuição de gênero, informações geográficas limitadas, métricas do desempenho de postagens individuais, bem como contas gerais alcançadas e informações de crescimento da conta, além de interações disponibilizadas como ferramentas disponíveis e dúvidas por *direct*. Todos os vídeos das entrevistas foram também adicionados ao YouTube, na página Algas pra que te quero. Todos os dados acessados foram compilados e serão apresentados nos resultados.

6 RESULTADOS E DISCUSSÃO

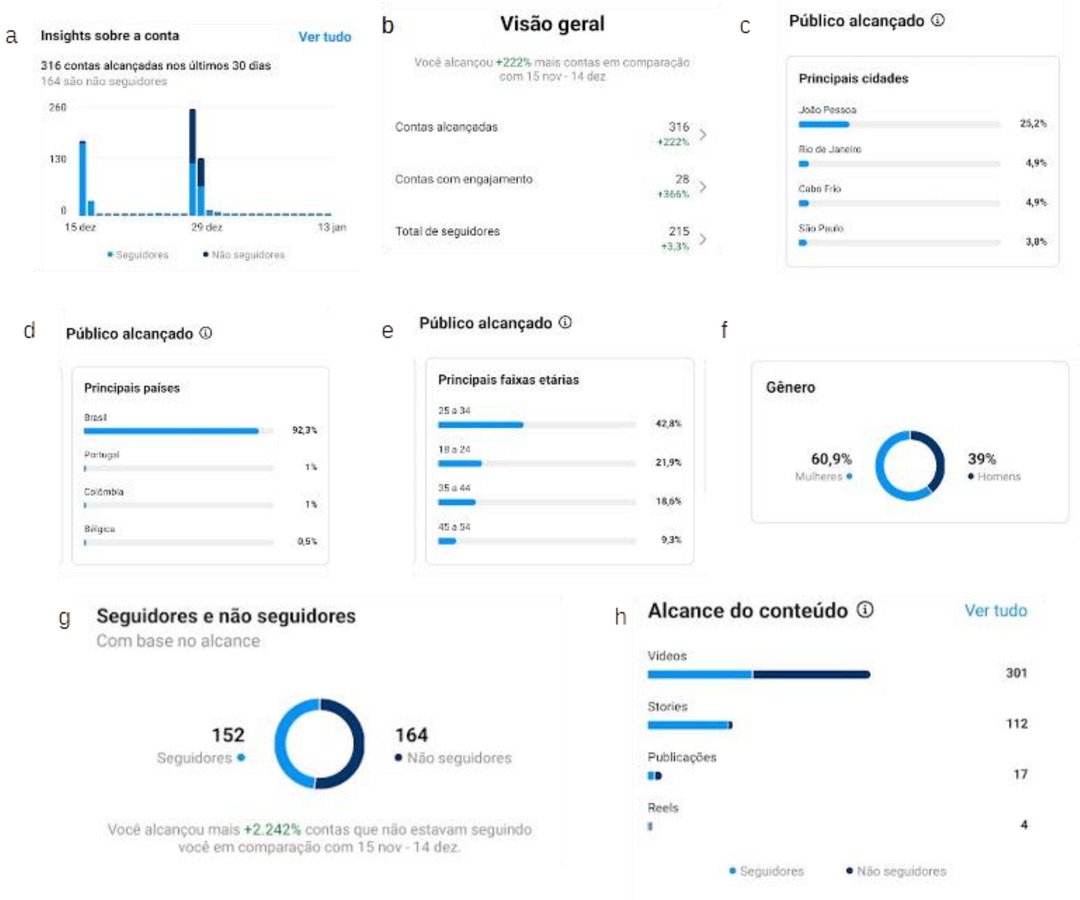
O presente trabalho trouxe resultados positivos para a divulgação científica na área de Biotecnologia Marinha e Algas através do uso de redes sociais para a comunidade acadêmica e alcançou o seu objetivo na medida em que apresentou o que foi proposto.

A linguagem de fácil acesso e o trabalho de atrair o interesse do público foi desafiadora inicialmente, mas a cada postagem, o alcance de mais pessoas era nítido. A conversa e a troca de ideias sobre informação científica na rede passam, assim, a ser entre atores não cientistas, em busca de informação que, a princípio, estava longe de seu alcance ou de pouco entendimento por ser um conteúdo técnico e estar claro somente para cientistas (MATEUS; GONÇALVES, 2012).

Em março de 2022, após nove meses da criação da página, nos *insights* (recurso da própria plataforma) foram alcançados, no total, 3.140 (três mil cento e quarenta) visualizações, conquistados 123 seguidores, com uma média de interação de 57,9% de média. Em dezembro de 2022, foram alcançadas 6.231 (seis mil duzentas e trinta e uma) visualizações, conquistados 215 seguidores, com uma média de interação de 60% de média. Essa contagem foi feita a cada postagem e somada, uma vez que, os dados permanecem disponíveis por dois meses antes de se tornarem inacessíveis na plataforma.

Ao analisar a postagem dos últimos 30 dias, vemos números e análises fornecidas pelos *insights* do Instagram (Figura 6) e pode-se entender que houve uma significativa participação e interação dos usuários com o conteúdo fornecido, muitas vezes de não seguidores da página. Todavia, inicialmente houve uma dificuldade inicial para simplificar a linguagem e manter a qualidade da informação, mas de acordo com a literatura (BUENO, 2009; CHASSOT, 2003; MASSARANI; MOREIRA; BRITO, 2002), era o esperado. Essas métricas baseadas em novas interpretações do conhecimento existente, podem ajudar a política e a prática científica a entender melhor como abordar áreas em que a ciência está desacelerando ou que precisa ocupar (WU *et al*., 2022).

Figura 6 - *Insights* fornecidos pelo Instagram do perfil @algaspraquetequero nos últimos 30 dias.



316 contas alcançadas nos últimos 30 dias
164 são não seguidores

Você alcançou +222% mais contas em comparação com 15 nov - 14 dez

Você alcançou mais +2.242% contas que não estavam seguindo você em comparação com 15 nov - 14 dez.

Fonte: Captura de tela feita pela autora; a)*Insights* sobre a conta nos últimos 30 dias, sendo 316 contas alcançadas, e dessas, 164 são não seguidores; b)*Insights* de visão geral, com mais de 222% a mais em comparação a 30 dias anteriores, mais de 366% em engajamento e mais 3,3% de seguidores comparados a esse mesmo período; c)*Insights* sobre o público alcançado em relação a cidade, sendo João Pessoa o maior público com 25,2%, seguidos de Rio de Janeiro (4,9%), Cabo Frio (4,9%) e São Paulo (3,8%); d)*Insights* sobre os principais países que alcançam a conta, com o Brasil em destaque (92,3%), seguido de Portugal (1%), Colômbia (1%) e Bélgica (0,5%); e)*Insights* sobre a faixa etária do público que acessou a conta, sendo em sua maioria entre 25 a 34 anos (42,8%); f) *Insights* sobre o gênero que acessou a página, sendo em sua maioria mulheres (60,9%); g)*Insights* sobre o alcance de público, sendo mais de 2.242% a mais que os últimos 30 dias, ou seja, 164 não seguidores que visualizaram a página; h)*Insights* sobre o interesse do público no conteúdo, onde vídeos tem maior acesso não de seguidores, mas também não seguidores.

A partir dessas métricas do *Instagram*, CASPARI (2022) revelou que as taxas de engajamento são usadas no marketing de mídia social para medir o quão bem o público interage com o conteúdo. A taxa atual de uma conta geralmente é medida por meio da média da taxa de engajamento dos últimos doze posts, e quando avaliadas com cuidado, podem fornecer um *feedback* útil e a primeira impressão da conexão de uma conta com seu público. O @algaspraquetequero obteve um alcance em 30 dias de aproximadamente mais de 366% de engajamento quando comparados a meses anteriores, com sua maioria de participação sendo mulheres (60,9%), e seu maior ponto de atrativo os vídeos das entrevistas com os pesquisadores.

Para além dos números, não existe a possibilidade de fazer ciência se o conhecimento estiver preso apenas a laboratórios ou a estudos guardados em estantes. O compartilhamento é um princípio moral que a comunidade científica idealmente adota. Trata-se de partilhar os avanços científicos (MERTON, 2013). A função da divulgação científica é facilitar o entendimento das informações e o interesse daquele público não especializado em ciência (MENDES; MARICATO, 2020).

As entrevistas com os pesquisadores da área foram de extrema importância para o público e o entendimento dos assuntos abordados. Como método, várias formas de entrevista permitem desvendar conhecimentos que, de outro modo, permaneceriam sob o radar de pesquisas formais e outras formas mais padronizadas de coleta de dados (FEDYUK; ZENTAI , 2018). Além disso, entrevistas não estruturadas em conversas informais, como as propostas pelo Algas pra que te quero, permitem que o entrevistado molde ativamente a entrevista e esclareça áreas que não foram originalmente entendidas.

Entrevistas como a da Izabel Christina Nunes de Palmer Paixão e o tema algas no combate aos vírus geraram debates e mais interesse, até pelo período pandêmico de COVID-19; foi abordado com o Dr. Leonardo Zambotti Villela o tema algas e bioeconomia, que dessa entrevista, gerou-se dezenas de compartilhamentos, mais de 294 contas alcançadas e um *networking* para a formação e escrita de artigo científico; em se tratando de Biodiversidade de algas no Brasil, a entrevistada foi com a Dra. Yocie Yoneshigue-Valentin, e o números foram impactantes; sobre o cultivo de algas e suas aplicações, a entrevistada foi com a Dra. Eliane Marinho Soriano, sua participação gerou mais de 450 contas alcançadas e mais de 40 interações com o conteúdo; assuntos relevantes para a sociedade como algas e doenças negligenciadas foram conversadas com a Dra. Márcia Aparecida Silva Graminha e com a Dra. Eliana Nakano, referências nessa área e juntas somaram mais de 540 visualizações, além do interesse do público; ao abordar as algas e a Biotecnologia Marinha, o Dr. Ricardo Coutinho foi o entrevistado, ele não só abordou os avanços na área, como divulgou oportunidades; ao pensar em algas e fungos endofíticos, a Dra. Hosana Maria Debonsi deu uma aula da importância e do diferencial de se trabalhar com produtos naturais; o Dr. Claudio Martin Pereira de Pereira conversou sobre algas e lipídios de impacto econômico; a Dra. Mutue Toyota Fujii conversou sobre a relevância da taxonomia de algas; assim como, a Dra. Nair Sumie Yokoya abordou a produção em laboratório de mudas de macroalgas e seus protocolos e a Dra. Marcella Araujo do Amaral Carneiro sobre as algas em cultivos multitróficos, com a sua significância para o meio ambiente; as algas também foram tratadas como biorremediadoras e bioestimulantes e quem conversou sobre isso foi Dr. Levi Pompermayer Machado; além das algas na ecotoxicologia com mais entrevista/aula do Dr. Ernani Pinto Junior. Todas as entrevistas e entrevistadores acima citados, estão disponíveis no *Instagram* da página e também no Youtube, no canal da Algas pra que te quero.

Essas entrevistas com os pesquisadores exploram suas experiências, e representam uma posição institucional das quais estão inseridos ou reflexões sobre questões que cerceiam a pesquisa, além de coletar informações que não são facilmente obtidas de fontes escritas (CHARMAZ, 2006). Em cada caso, uma entrevista abrange uma conversa, na qual o entrevistado compartilha sua experiência, opiniões, memórias e conhecimentos. Um exemplo foi a entrevista com professora Marcella Araújo do Amaral Carneiro, em agosto de 2022, intitulado como Algas em sistemas de cultivo multitrófico - Profa. Dra. Marcella Amaral, onde ela cita sua experiência na troca de conhecimento com comunidades litorâneas, em um trecho retirado da conversa:

> “[…] o cultivo de alga nos preocupa mediante a superexploração, e o excesso de extrativismo que possa causar algum problema ambiental, então quando desenvolvemos a atividade de cultivo, tivemos a oportunidade de junto a comunidade local repassar todo o nosso conhecimento, para que essas pessoas que já trabalhavam na atividade tradicional de coleta de alga tivessem o entendimento do ciclo de reprodução e o manejo adequado para aquela determinada espécie de alga, para que esse recurso não acabe.” (AMARAL, 2022)

Essa entrevista e as demais, foram além do artigo acadêmico e de seu método científico, uma vez que a conversa evoluía e os relatos eram feitos de modo a revelar a vivência da Ciência, até então, desconhecida pela maioria dos que assistiram a entrevista. Portanto, não é de surpreender que a entrevista tenha se tornado parte integrante do processo de conhecimento, uma vez que, até as curiosidades reveladas pelos pesquisadores são formas de aprendizado (GRUBER; VALJI; RANGANATH, 2019).

O tema abordado pelo @algaspraquetequero foi a Biotecnologia Marinha e as Algas, portanto, elucidar que os ambientes marinhos fornecem uma infinidade de serviços ecossistêmicos que levam a benefícios sociais (TOWNSED *et al*., 2018) foi um dos objetivos a cada postagem e entrevista. Ao levar em conta que, definir Biotecnologia Marinha era essencial inicialmente, pois os recentes avanços da ciência e da tecnologia têm facilitado a sua implementação no cotidiano, e isso foi exposto pelo entrevistado Dr. Ricardo Coutinho, chefe do Departamento de Biotecnologia Marinha, Coordenador do curso de Pós-graduação em Biotecnologia Marinha (IEAPM/UFF) e credenciado no curso de Pós-Graduação em Dinâmica dos Oceanos e da Terra (UFF). Onde mostrar para a sociedade, pela mídia social, que os organismos marinhos, salvo aqui as algas, e seus compostos são identificados na taxonomia, extraídos, isolados, caracterizados e utilizados para aplicações em diversos setores em prol da sociedade, desde alimentos/ração animal até produtos farmacêuticos e biomédicos industriais é imprescindível. E ainda vale lembrar a todos que acompanhavam a página que, os recursos marinhos permanecem amplamente subexplorados e subvalorizados (ROTTER *et al*., 2021).

Por conseguinte, viabilizar a aprendizagem de ter a habilidade da comunicação científica requer tempo e esforço, e ao utilizar as mídias sociais, essa comunicação é rápida e direta. O pesquisador passa a informação com maior domínio de sua pesquisa, em um nível de linguagem e simplificação que seja atrativa, preservando o conteúdo científico e transpondo a barreira do nicho acadêmico. E, ao obter o conhecimento como um produto a ser divulgado, deve-se notar que a ideia do *Instagram* de proporcionar um material colorido ou um espaço bonito para o desenvolvimento de um ambiente para o cientista mostrar sua pesquisa, faz com que entender e aprender seja muito mais prazeroso e esse processo seja mais proveitoso para o leigo (LEAL, 2019).

O *Instagram* pode ser usado para essa comunicação e troca de conhecimento. Logo, deve ser a tendência dos próximos anos, uma vez que, com cerca de um bilhão de usuários ativos mensais, mais de dois terços de seus usuários têm 34 anos ou menos, o que sugere a importância dessa mídia social no futuro (ANDERSON *et al*., 2018), não só para fins sociais, como científicos.

7 CONCLUSÃO

O presente trabalho trouxe resultados positivos para a divulgação científica da Biotecnologia Marinha e Algas, através do uso de redes sociais para a comunidade acadêmica.

O pesquisador convidado pôde disseminar o conhecimento de forma simples e favorável ao tema, levando o público a interagir e buscar mais sobre essa grande área.

As redes sociais ampliaram os horizontes da Ciência, mas ainda pode crescer mais, visto que seu alcance depende do interesse do público no assunto. Divulgar o que acontece nos nichos acadêmicos por meio do Instagram hoje é uma estratégia de posicionamento que todo profissional pode utilizar.

Esse trabalho segue sendo executado, a página seguirá divulgando sobre Biotecnologia Marinha e Algas, gerando ainda mais estímulo não só para o pesquisador, mas também para a sociedade, como forma de se atualizar e solidificar a ponte academia e sociedade.

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1 PREFÁCIO CAPÍTULO 2

O conhecimento é criado nas organizações, assim é estabelecida a Teoria da criação do conhecimento organizacional. O capítulo anterior elucidou a importância da divulgação científica e a rede de conexões que o compartilhamento de conhecimento pode ampliar. Portanto, era de se esperar frutos e resultados positivos de abordar Ciência, Biotecnologia Marinha e Algas, como o capítulo seguinte.

Em uma das várias entrevistas que o projeto “Algas pra que te quero?” se propôs a realizar, uma delas obteve-se um produto gerado, além daquele espaço, um manuscrito. A entrevista sobre o tema Algas e Bieconomia, realizada com o Dr. Leonardo Zambotti Villeva, evoluiu de uma conversa e dúvidas para uma forma de solucionar questões econômicas envolvendo esses assuntos. BOGNER E MENZ (2009) abordaram essa ideia, ao citar:

> “[...] Entrevistas com especialistas podem servir para estabelecer uma orientação inicial em um campo substancialmente novo ou mal definido, como forma de ajudar o pesquisador a desenvolver uma ideia mais clara do problema ou como um movimento preliminar na identificação de um guia final de entrevista. Nesse sentido, as entrevistas exploratórias ajudam a estruturar a área investigada e a gerar hipóteses.”

A partir desse pressuposto, e de que, o conhecimento está disperso na sociedade, como estabelecido por FRIEDRICH A. VON HAYEK (1985), responder as lacunas e indagações do espaço entre academia e indústria, por meio de uma revisão bibliográfica organizacional foi buscada. O produto disso pode ser visto no capítulo seguinte.

2 CAPÍTULO 2

“Biorrefinaria de macroalgas para a indústria cosmética: conceito básico, tecnologia verde e diretrizes de segurança”

3 INTRODUÇÃO

Os cosméticos têm sido aplicados desde os tempos antigos em muitas civilizações para fins artísticos, embelezadores, protetores, de limpeza e cerimoniais. A palavra "cosmético" é derivada do grego Kosm tikos, que significa "tendo o poder de organizar, habilidoso em decorar”, “kosmein", 'adornar' 'e kosmos' 'ordem, harmonia' ', mas a verdadeira origem dos cosméticos provavelmente está ainda mais na antiguidade, porque as primeiras pinturas rupestres de 30.000 anos atrás retratam o uso de adornos corporais (cosméticos rudimentares) nos rituais de acasalamento e caça (CHAMBERS *et al*., 1996). Alexandre, o Grande (356-323 a. C.) relatou o uso de unguentos, incenso e outros cosméticos pelos países da civilização Indo Suméria (MILSTEIN *et al.*, 2005), portanto, os cosméticos fazem parte das culturas de diferentes civilizações.

Durante a década de 1980, a busca das mulheres sobre nutrição e seus efeitos em seus corpos e pele começou a crescer. As mulheres realmente consideravam o que colocavam no rosto e usavam cremes que auxiliam no condicionamento e na preservação da pele. A era dos baby boomers viu muitos produtos que melhoraram visivelmente a pele das mulheres. Isso levou diretamente ao aumento das vendas desses produtos, bem como de cosméticos para aplicar na pele saudável. Tendências de maquiagem focaram em looks ousados e exagerados. (HUNT; FATE; DODDS, 2011).

Os cosmecêuticos são conhecidos como cosméticos com propriedades terapêuticas. Durante a década de 1990, os cosmecêuticos se tornaram cada vez mais populares (GERSON, 2004). Não só eram seguros para aplicar na pele, como também melhoravam a aparência da pele e a saúde geral. Para as mulheres, foram colocados à disposição produtos anti-envelhecimento, bem como produtos que promovam a saúde de dentro para fora, com o uso de vitaminas e suplementos. Procedimentos de pele, como microdermoabrasão e nivelamento da pele epidérmica, eram comumente praticados para limpar e refrescar a pele. As escolhas de maquiagem natural tornaram-se populares novamente durante os anos 90. Modelos como Cindy Crawford, Christy Turlington e Naomi Campbell influenciaram as mulheres e suas escolhas quando se tratava de roupas e maquiagem. Os bronzeados falsos tornaram-se extremamente populares ao longo dos anos 90. Camas de bronzeamento, banhos de sol e produtos de bronzeamento logo foram adicionados ao regime de beleza (HUNT; FATE; DODDS, 2011).

Ao analisar todo esse processo de demanda e mudança de vontades e usos dos cosméticos em sociedade, pode ser observado que tudo começou quando as pessoas criaram suas próprias misturas e poções em suas casas e tornou-se a capacidade de qualquer pessoa no mundo comprar qualquer produto, virtualmente, a qualquer momento que deseje.

A expansão do consumo de produtos desenvolvidos com bases naturais vai de encontro com alguns dos novos valores da sociedade contemporânea e que estão relacionados à qualidade de vida em geral, à beleza, ao bem-estar e ao prazer, onde a saúde, a estética, a juventude e a aparência saudável poderiam, dentre outros fatores, ser obtidas a partir do uso de ingredientes e formulações da "natureza" (MIGUEL, 2011).

Ao passar dos anos, a pele recebeu notável cuidado e incentivo por parte da indústria, tornando-se em 2016, de acordo com a Indústria Europeia, um mercado avaliado em € 77 bilhões no preço de venda no varejo, seguido pelos Estados Unidos (€ 64 bilhões) e Brasil (€ 24 bilhões). Essa indústria está sempre em busca de novos ingredientes, principalmente por dois motivos - o primeiro sendo por critérios de marketing ~~óbvios~~ e o segundo sendo para substituir matérias-primas que foram proibidas ou passaram a ser desconfiadas pelo consumidor ao longo das décadas (COUTEAU; COIFFARD, 2016).

Nos últimos anos, as preocupações com a saúde e a demanda por produtos naturais têm incentivado pesquisas sobre fontes abundantes e alternativas de novos ingredientes e aditivos e novos processos que envolvam sustentabilidade. Os recursos marinhos representam uma fonte subexplorada de compostos valiosos altamente diversos com aplicações potenciais em diferentes setores, um deles sendo a área de cosméticos. As indústrias de cosméticos, também influenciadas pelas preferências dos consumidores, têm cada vez mais incorporado ingredientes naturais em diferentes produtos. Porém, o mercado de cosméticos naturais ainda representa uma fração menor em relação aos cosméticos convencionais.

As algas marinhas são ricas em compostos bioativos que podem ser explorados como ingredientes funcionais para aplicação cosmética. Compostos com ações antioxidantes, fatores de crescimento, peptídeos, agentes anti-inflamatórios e clareadores de pigmento são algumas das diferentes funções que as algas podem proporcionar aos mais diversos produtos. Além da sua produção pode ser totalmente verde e com conceitos de biorrefinaria que agreguem valor não só ao produto, mas ao processo também.

4 OBJETIVOS

OBJETIVO GERAL

Diante da vasta aplicação das algas e a sua relevância para a indústria de diversos setores, essa revisão bibliográfica tem por objetivo realizar um apanhado de compostos desse organismo fotossintético marinho nos últimos dez anos (2010 a 2021) e a sua participação principalmente no setor de cosméticos, além de buscar alternativas para uma produção sustentável para a indústria.

OBJETIVOS ESPECÍFICOS

- Desenvolver uma pesquisa bibliográfica, a qual consiste em um levantamento, seleção e documentação da bibliografia já publicada em determinado período sobre o assunto que está sendo pesquisado em livros, revistas, sites e artigos com o objetivo de colocar o pesquisador em contato direto com todo material já escrito sobre o tema;
- Utilizar de plataformas como o *Google Acadêmic* e *Scielo, Lilacs*, bem como, banco de dados de patentes, análises de mercado, livros, artigos e periódicos a fim de estabelecer o tema abordado;
- Apresentar vias de produção sustentáveis para a indústria, seguindo diretrizes da Organização para a Cooperação e Desenvolvimento Econômico (OCDE);
- Expandir os horizontes dos bioprodutos proporcionados pelas algas para além de uma única aplicabilidade em um só produto cosmético.

5 MANUSCRITO

“Macroalgae Biorefinery for cosmetic industry: basic concept, green technology, and safety guidelines”

Macroalgae Biorefinery for cosmetic industry: basic concept, green technology, and safety guidelines

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1. ABSTRACT

With the growth in the search for personal care, the consumer finds the solution in cosmetic products. However, this demand is currently made concomitantly with products of natural origin, including seaweed. Algae, in its composition, are full of bioactive compounds with several applications. Therefore, its insertion in cosmetics is evidenced in the high number of scientific studies, which makes this natural resource potential for the cosmetic industry. From this, this review aimed to highlight some of these active compounds, as well as the latent applicability and versatility of others. In addition, the best way to add to the production of these substances in alignment with green consumption, the design of a biorefinery, and the promising production of macroalgae on a large scale using green technologies was sought.

Keywords:

2. INTRODUCTION

In recent years, concerns about the environment and wellness of society have been driving the industry's demand for natural products. This behavior encouraged private and public investments in research on the comprehensive use of renewable resources to produce more sustainable ingredients. Along with this demand, policies, *e.g.*, from European Commission for Bioeconomy (European and Directorate-General for Research And, 2018) and Blue Bioeconomy Forum (European and Executive Agency for Small and Medium-Sized, 2020), and international guidelines, *e.g.*, from ISO 16128-2:2017 (I.S.O., 2017) are contributing to industry and other stakeholders to achieve the Sustainable Development Goals (SDGs) from United Nations (U.N., 2015).

Among the renewable resources that show potential for manufacturing innovative green ingredients for different economic activities, are the ones from aquatic or marine environments (European and Executive Agency for Small and Medium-Sized, 2020). They are underexploited resources despite the fact of having diverse high-added-value compounds with potential applications in food and feed, cosmetic and pharmaceutical industries. Within the group of marine organisms, there are macroalgae, which are rich in bioactive compounds that can be explored as functional ingredients. This diversity of components is due to the survival power of these marine algae in a competitive environment, which have developed defense strategies that result in a significant level of chemical-structural diversity, from different metabolic pathways (Cardozo *et al*., 2007). Compounds with antioxidant activities, growth factors, anti-inflammatory agents, and pigment whitening are some of the different functions that algae can provide for the most diverse products (Table 1).

Cosmetics have been applied from ancient times in many civilizations for artistic purposes, embellishers, protectors, cleaning, and ceremonial. The word cosmetic is derived from the Greek Kosm Tikos, which means means having the power to organize, skillful in decorating, Kosmein, Adorn and Kosmos which means Order and Harmony, but the true origin of cosmetics is probably even more in antiquity because the first rushing paintings of 30,000 years ago portray the use of bodily adornments (rudimentary cosmetics) in the rituals of mating and hunting (Chambers *et al*., 1996). Alexandre, the Great (356-323 a. C.) reported the use of ointments, incense, and other cosmetics by the countries of Civilization Indumer (Barel *et al*., 2009), therefore, cosmetics are part of the cultures of different civilizations.

Over the years, the skin received remarkable care and incentive by industry, becoming in 2016, according to European Industry, a market rated at € 80 billion in retail sale price, followed by the United States (€ 64 billion) and Brazil (€ 24 billion), and the tendency of these values is only to increase. This industry is always searching for new ingredients, especially for two reasons - the first being by obvious marketing criteria and the second being to replace raw materials that have been banned or become suspicious by the consumer throughout the decades (Couteau; Coiffard, 2016), being macroalgae, the targets of the moment when it comes to innovation in ingredients and efficiency in this area.

3. OVERVIEW OF MARINE MACROALGAE CHEMICAL COMPOSITION AND BIOACTIVITIES

The phylum classification of marine macroalgae concerns the prevalence of their pigments, *i.e.*, fucoxanthin for brown (Phaeophyta), phycobiliproteins for red (Rhodophyta), and chlorophyll for green (Chlorophyta) algae. According to AlgaeBase (2022), there are 168,376 species and intraspecific names of algae (macroalgae and microalgae). However, only a few species are raw materials for industry regardless the known bioactivity of ingredients extracted from macroalgae (Table 1).

Carbohydrates and lipids are structural molecules and part of the primary metabolism of macroalgae. Both molecule classes are commercially explored and share a great interest mainly with the food, cosmetic, and pharmaceutical industries since they include polysaccharides (such as agar, carrageenan, fucoidan, alginates, etc.) and long-chain polyunsaturated fatty acids (such as the omegas-3 docosahexaenoic acid and eicosapentaenoic acid). In recent years, because of the rising interest in non-animal protein, macroalgae have been also explored as a renewable source of proteins with a forecast market value of US$ 1.51 billion for 2030 (Naga *et al.*, 2022).

Besides these molecules, much of the bioactivities of macroalgae extracts are from compounds of the secondary metabolism that often are at trace levels of detectability. Bioactivity can also be derived from synergies between compounds within an extract, and in some cases, not being a derived property of any individual compound present in the extract, it can be lost through compound separation and purification (Stengel *et al.*, 2011).

Table 1. Putative efficacy of some chemical classes from macroalgae (2012 to 2022).

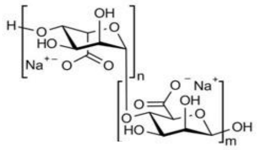
Putative efficacies/activities	**Polysaccharides**	**PUFA**	**Mycosporine-like amino acids**	**Phenolic compounds**	**Pigments**	**Sterols**
Anti-acne					(Kok *et al.*, 2016)	
Anti-inflammatory	(Ozanne *et al.*, 2020; Wang *et al.*, 2020; Januário *et al.*, 2021; Kalasariya *et al.*, 2021)	(Berthon *et al.*, 2017; Januário *et al.*, 2021)	(Berthon *et al.*, 2017; Januário *et al.*, 2021; Pangestuti, Shin, *et al.*, 2021)	(Berthon *et al.*, 2017; Januário *et al.*, 2021; Lee *et al.*, 2022)	(Berthon *et al.*, 2017; Pangestuti, Shin, *et al.*, 2021)	(Meinita *et al.*, 2021)
Anti-photoaging	(Berthon *et al.*, 2017; Fernando *et al.*, 2020; Pangestuti, Shin, *et al.*, 2021; Lee *et al.*, 2022)		(Pangestuti, Shin, *et al.*, 2021)	(Berthon *et al.*, 2017)	(D'orazio *et al.*, 2012; Pangestuti, Shin, *et al.*, 2021)	(Meinita *et al.*, 2021)
Anti-skin aging	(Freitas *et al.*, 2020; Kalasariya *et al.*, 2021)			(Freitas *et al.*, 2020)		(Hannan *et al.*, 2020)
Anti-wrinkling	(Jesumani *et al.*, 2019; Freitas *et al.*, 2020;			(Gam *et al.*, 2021)		

Putative efficacies/activities	**Polysaccharides**	**PUFA**	**Mycosporine-like amino acids**	**Phenolic compounds**	**Pigments**	**Sterols**
	Kalasariya *et al.*, 2021)					
Antiapoptotic	(Wang *et al.*, 2019; Fernando *et al.*, 2020)			(Zhen *et al.*, 2019)		
Antioxidant	(Jesumani *et al.*, 2019; Wang *et al.*, 2019; Jesumani *et al.*, 2020; Lee *et al.*, 2022)		(Pangestuti, Shin, *et al.*, 2021)	(Berthon *et al.*, 2017; Freitas *et al.*, 2020; Jesumani *et al.*, 2020; Lee *et al.*, 2022)	(Berthon *et al.*, 2017; Pangestuti, Shin, *et al.*, 2021; Lee *et al.*, 2022)	(Berthon *et al.*, 2017)
Antipollution				(Zhen *et al.*, 2019)		
Depigmenting and bleaching lightening	(Freitas *et al.*, 2020; Jesumani *et al.*, 2020; Kalasariya *et al.*, 2021; Lee *et al.*, 2022)			(Berthon *et al.*, 2017; Jesumani *et al.*, 2020; Gam *et al.*, 2021)	(Berthon *et al.*, 2017)	

Putative efficacies/activities	**Polysaccharides**	**PUFA**	**Mycosporine-like amino acids**	**Phenolic compounds**	**Pigments**	**Sterols**
Hair growth				(Sanjeewa *et al.*, 2016)		
Hydration	(Jesumani *et al.*, 2020)			(Jesumani *et al.*, 2020)		
Photoprotection	(Jesumani *et al.*, 2020)		(Berthon *et al.*, 2017; Pangestuti, Shin, *et al.*, 2021)	(Berthon *et al.*, 2017; Jesumani *et al.*, 2020)	(Berthon *et al.*, 2017; Pangestuti, Shin, *et al.*, 2021)	
Skin barrier	(Lee *et al.*, 2022)				(Pangestuti, Shin, *et al.*, 2021)	
Wound healing	(Bilal and Iqbal, 2020; Lu *et al.*, 2022)					

3.1 Polysaccharides

The polysaccharides are the most significant and beneficial compounds present in macroalgae for industry, having many different types, such as agar, carrageenan, laminarin, alginates and ulvan (Usov and Zelinsky 2013). The main macroalgae polysaccharides are sulfated and include, alginates **(1)**, fucoidan **(2)**, and laminarin **(3)** in brown, agar **(4)** and carrageenan **(5)** in red, and ulvan **(6)** in green macroalgae. Moreover, they have a wide variety of bioactivities that may have applications in cosmetic industry, such as anti-inflammatory, anti-photoaging, anti-skin aging, anti-wrinkling, antiapoptotic, antioxidant, depigmenting and bleaching lightening, hydration, photoprotection, skin barrier, and wound healing (Table 1). One of the most important functional requirements of polysaccharides is that they must be stable during industrial process conditions such as high temperature, various pH, and ionic strengths (Torabi *et al.*, 2022).



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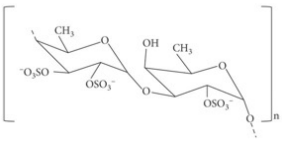

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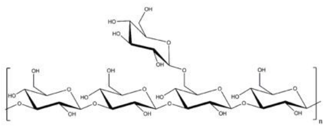

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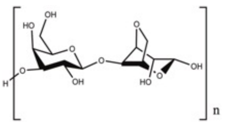

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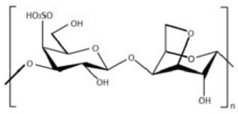

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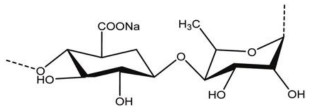

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3.2 Polyunsaturated Fatty Acids (PUFA)

The physical and biochemical characteristics of PUFAs play an essential role in the survival and growth of microorganisms and aquatic animals in some hostile environments. Among these compounds (omega-3, omega-6, and omega-9) are the long-chain omega-3 of great interest of the industry, such as eicosapentaenoic acid (EPA) **(7)** and docosahexaenoic acid (DHA) **(8)**. PUFA are essential for human diet, and mainly used in food and pharmaceutical industry. It happens because a omega-6/omega-3 ratio of 3:4 is advised for health benefits related to their consume (Harwood, 2019). Likewise, the World Health Organization currently recommends an omega-6/omega-3 ratio up to 10 (Francavilla *et al.*, 2013).

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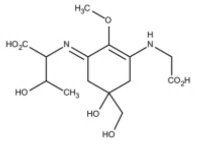
Otero *et al.* (2018) evaluated several macroalgae from Northwest of Spain, including the brown *Fucus vesiculosus* and green *Ulva lactuta* algae, and subjected them to liquid extraction to obtain high-quality fatty acids, including omega-3. Besides the application as nutraceutical, the authors found relevant antioxidant and antimicrobial activities.

Considering the search for new natural preservatives, these findings have potential of application in the cosmetic industry. However, there are only few studies with PUFA and skin care cosmetics (Table 2).

3.3 Mycosporine-like Amino Acids

When exposed to UV radiation, macroalgae synthesize different defense mechanisms to deal with it, one of them are the mycosporine-like amino acids (MAAs), which consists of cyclohexenimine ring conjugated with two amino acids, amino alcohol, or amino group substituents (Singh *et al.*, 2020). These compounds are capable of dissipating absorbed radiation as harmless heat without producing reactive oxygen species (ROS). This characteristic makes them act as an option for sunscreens and provide additional protection as antioxidants (Lalegerie *et al.*, 2019). Furthermore, the antioxidant activity of seaweed-derived MAAs such as porphyra-334 **(9)**, shinorine **(10)**, asterina-330 **(11)**, palythine **(12)** and mycosporine-glycine (Myc-Gly) **(13)** have been tested in various assays (Pangestuti *et al.*, 2021). These photoprotective compounds have been isolated from various macroalgal species, mainly in Rhodophyta (Bedoux *et al.*, 2020) and they have maximum UV absorption between 310 and 362 nm (Rastogi *et al.*, 2010). It is noteworthy that these MAAs are considered the greatest absorbers of UVA in nature and some of them can even act as antioxidants (Rangel *et al.*, 2020)



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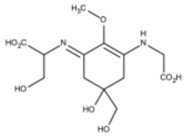

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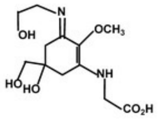

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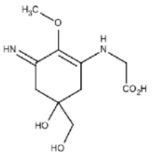

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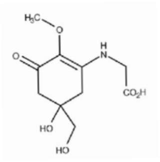

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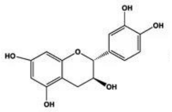
3.4 Phenolic Compounds

These macroalgae are rich in various phenolic compounds, such as catechins **(14)**, flavonols **(15)**, flavonolglycosides **(16)**, phloroglucinol **(17)**, gallic acid **(18)**, epicatechin **(19)**, pyrocatechol **(20)**, gallate **(21)**, flavonoids **(22)**, anthocyanins **(23)**, stilbenes **(24)**, lignans **(25)**, phenolic polymers **(26)** (Kalasariya *et al.*, 2021), and these compounds phenols and flavanols are already describe as having antioxidant activity, with tests like ABTS radical scavenging assay and DPPH radical scavenging assay. Considering that, from a chemical point of view, phenolic compounds are formed by a structural nucleus based on a hydroxyl group linked directly to phenol, and that this configuration gives them the ability to capture free radicals, reactive oxygen species, and chelated metal ions (Jimenez-Lopez *et al.*, 2021), it is to be expected that its action as an antioxidant, in addition to anti-inflammatory agents and immune system modulators, are obtained and maintained by being extracted and isolated from macroalgae. Beyond that, some substances derived from these phenolic compounds, like tannins, a phenolic acid, and with his group, phlorotannins **(27)**. Phlorotannins are type of tannins found in brown algae such as kelps and rockweeds or sargassaceae species, and in a lower amount also in some red algae, they play a role as inducible screens against harmful UV radiation and it has antioxidant activity too (Ahn *et al.*, 2007).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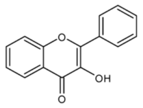
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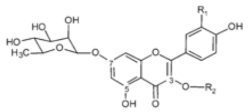
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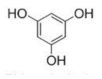
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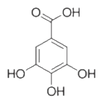
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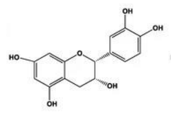
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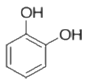
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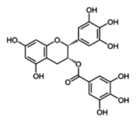
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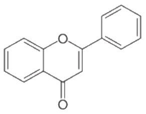
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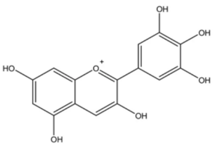
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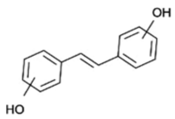
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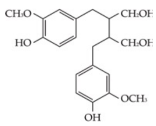
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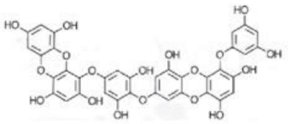
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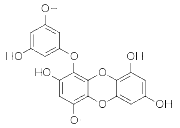
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Phenolics also have a photoprotective function, as shown in macroalgae that improve the production of UV-absorbing (phenolic) compounds through exposure to UV, to mitigate and even prevent the damage caused. This only supports the results obtained by Polo and Chow (2022) on the *Sargassum felipendula* extract, subjected to radiation, which tends to have a high antioxidant potential, as the alga is expected to develop a very effective antioxidant defense system, due to the strong UV incidence, for their survival. It is not by chance that this extract and this genus is used as skin protection agent (Table 2).

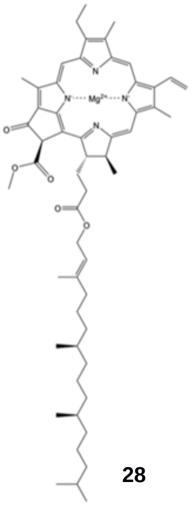
According to Tsao (2010), flavonoids are the largest and most diverse group of bioactive natural products categorized under the family of polyphenols, and green algae represent the most primitive type of plant species that contain them. As they are present in this family of polyphenols, they are listed as UV-protecting antioxidants and anti-predatory toxicants, however, when dealing specifically with flavonoids in algal species, their bioactive properties remain little explored (Fernando *et al.*, 2020).

However, plant species and their flavonoid-rich extracts have been studied in dermatology and cosmetic preparations due to their strong antioxidant, anti-inflammatory, antimicrobial, and affinity/inhibition effects concerning specific enzymes that promote inflammation (Saul *et al.*, 2017), so the flavonoids from algae have this action potential.

Studies by Castejon et al. (2021), for example, performed a screening on potential cosmetic applications of aqueous extracts of three Icelandic algae, including *Ulva lactuca*, evaluating the content of polyphenols, flavonoids, and carbohydrates. With the results, they were able to obtain a high content of these bioactive, to correlate flavonoid activities, despite being scarce in the literature, and they saw that their use in skin whitening, and anti-aging products is positive, since they suggest that the tyrosinase inhibitory activity was positively correlated with flavonoid and phenolic content. It is noteworthy that tyrosinase plays an important role in the biosynthesis of the pigment melanin in the skin (Brenner and Hearing, 2008). And this melanin is responsible for protecting against harmful ultraviolet radiation, which can create aesthetic problems when accumulated, the famous hyperpigmented spots (Lee *et al.*, 2016). Consequently, the attachment of tyrosinase inhibitors in cosmetics can be attractive due to the lightening and/or lightening effects.

3.5 Pigments

In addition to the compounds mentioned previously, macroalgae contain a broad range of photosynthetic pigments chlorophylls **(28)**, carotenoids **(29)** (carotenes, xanthophylls, fucoxanthin, and peridinin), and phycobiliproteins **(30)** (phycocyanin and phycoerythrin) (Costa *et al.*, 2011). Carotenoids, for example, are photoreceptors present in algae, which absorb light energy and transport it to the electron transport chain. In addition to this function, they protect chloroplasts from excess light radiation and reactive species generated during oxygenated photosynthesis (Caferri *et al.*, 2022), therefore with an antioxidant function attributed and of interest to cosmetics, as they have also been used as stabilizers and as preservatives in creams and lotions for solar protection (Jahan *et al.*, 2017). These pigments are algae-derived metabolites and have a diversified profile, applied in various applications, such as anti-acne, anti-inflammatory, anti-photoaging, antioxidant, depigmenting and bleaching lightening, photoprotection, and skin barrier (Table 1).



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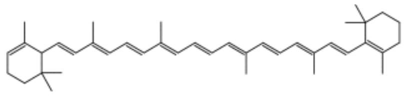

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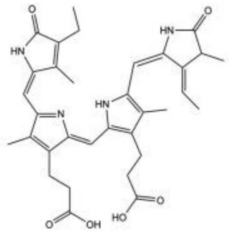

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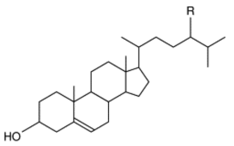
3.6 Sterols

Other important bioactive substances obtained from algal sources are sterols, which are present in the cell membrane and influence cell functions. They are found in many forms: free sterols **(31)**, sterol esters **(32)**, alkyl sterol ethers **(33),** sterol sulfates **(34)**, or linked to a glycosidic moiety **(35)** (Benveniste, 2004), but despite their consistent presence, sterols are found in distinctly different compositions across kingdoms and among the algae.



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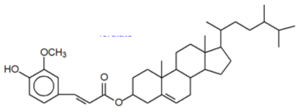

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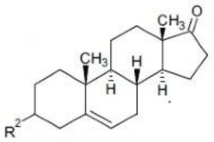

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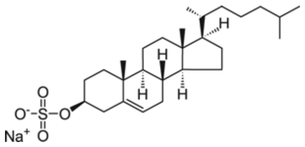

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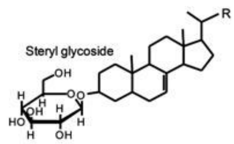

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In terms of functionality, most studies report that foods containing these sterols can lead to decreased absorption of cholesterol and reduced serum levels of low-density lipoprotein cholesterol (Brufau *et al.*, 2008), which is beneficial for human health. In the case of cosmetics, sterols are used as hydrating agents that limit water loss through different mechanisms, in addition to being used in conjunction with humectant substances on the surface of the skin to attract water, which is a form of hydration. It has also been shown that macroalgae sterols has anti-inflammatory, anti-photoaging, anti-skin aging and antioxidant actions that may be explored by cosmetic industry (Table 1).

4 THE APPLICATION OF ALGAE EXTRACTS IN COSMETICS

For the Food and Drug Administration (FDA), in the United States of America (USA), cosmetics are products that, when applied to the human body, cleanse, beautify, promote attractiveness, or modify the appearance of the skin and hair or the body, without affecting its structure or function (Ribeiro, 2010) .

During the last decades, the toxicological safety of cosmetics and their ingredients has attracted increasing attention (Nohynek *et al.*, 2010). This is revealed when analyzing the growing register of interest in the products under the label of “natural” and in the case of biodiversity, it gains strategic value over its possible industrial and economic uses in different segments. Through this trend, grows in the world and, mainly, in European countries, a consumer market increasingly adept of the campaigns of the so-called “green consumption”, that is, of products made based on natural actives, as in the case of those developed by the cosmetics industry (Suphasomboon and Vassanadumrongdee, 2022).

Nowadays, in the cosmetic field, there are more concepts in this area, like clean beauty, which in a nutshell, refers to skincare products that are clean of harmful ingredients. This sometimes indicates that clean beauty brands use natural ingredients, meantime still using synthetic ingredients that have been deemed safe for consumers’ health and the environment (Brooking, 2021). As the market moves toward minimalist beauty, today’s consumer demands brands with cleaning up their products, while rising to meet their expectations. From that idea, then arises the minimal formula, where skincare brands formulate products with fewer chemical ingredients, simple packaging, and intelligence. This makes them eco-friendly, and sustainably provides comfort and transparency for consumers concerned about their impact on the environment.

As aforementioned, macroalgae produce a wide variety of chemically active primary and secondary metabolites that are in their surroundings, potentially as an aid to protect themselves against the other settling organisms. These active metabolites, also known as biogenic compounds, such as halogenated compounds, alcohols, aldehydes, terpenoids are produced by several species of marine macroalgae, and have antibacterial, and antifungal properties, as in therapeutics (Kolanjinathan *et al.*, 2014). Furthermore, these metabolites present opportunities to explore these molecules and find novel and natural bioactive compounds.

Based on the search of industrial and commercial literature, it was observed that the main applications for seaweed extracts in cosmetics are for skincare (Table 2). They are established in the market for products for the face and skin, such as anti-aging and regenerating creams, refreshing products, emollients, anti-irritants, sun protection, and hair care products.

Table 2. Examples of macroalgae extracts used as ingredients by the cosmetic industry.

INCI Name	**Type (color)**	**Ingredient name**	**INCI Functions**
Hypnea musciformis Extract	Rhodophyta	Algae hypnea contains alginic acid, mannitol, carrageenan, galactosides, amino acids, mineral salts, oligoelements, vitamins and pigments	skin protecting
Gelidiella acerosa Extract	Rhodophyta	Hypnea Musciformis Extract(and) **Gelidiella Acerosa Extract (and)** Sargassum Filipendula Extract (and) Sorbitol	skin protecting
Sargassum filipendula Extract	Phaeophyta	Hypnea Musciformis Extract(and) Gelidiella Acerosa Extract (and) **Sargassum Filipendula Extract** (and) Cellulose	skin protecting
Ahnfeltiopsis concinna extract	Rhodophyta	Ahnfeltia Concinna Extract	viscosity controlling
Botryocladia occidentalis extract	Rhodophyta	Water (and) **Botryocladia Occidentalis Extract** (and) Hypnea Musciformis Extract (and) Sargassum Vulgare Extract	skin conditioning
Chondrus crispus extract	Rhodophyta	Chondrus Crispus Extract	film-forming, skin smoothing and moisturizing properties, viscosity controlling
Ascophyllum nodosum Extract	Phaeophyta	Ascophyllum nodosum Extract	skin conditioning, may help protect against UVB ray
Laminaria Ochroleuca Extract	Phaeophyta	Caprylic/Capric Triglyceride (and) **Laminaria Ochroleuca Extract**	skin conditioning

INCI Name	Type (color)	Ingredient name	INCI Functions
Kappaphycus alvarezii Extract (Telosomyl)	Rhodophyta	Water (and) **Kappaphycus Alvarezii Extract (and)** Laminaria Saccharina Extract (and) Hydrolyzed Rice Protein	skin conditioning
Laminaria digitata Extract (Horsetail Kelp Extract)	Phaeophyta	Aqua (and) Propylene Glycol (and) **Laminaria Digitata Extract**	skin protecting
Porphyra Yezoensis Extractr (Pyropia yezoensis)	Rhodophyta	Water (and) Butylene Glycol (and) **Porphyra Yezoensis Extract**	skin conditioning
Eisenia bicyclis extract	Phaeophyta	Aqua, Aloe Barbadensis, Cocos Nucifera Milk, Melaleuca Oil, Cucumis Sativus, Anthemis Nobilis, Hyaluronic Acid, Camellia Sinensis, Xanthan Gum, **Arame Algae Extract**, Vitis Vinifera, Matricaria Chamomilla, C, Betaine, Lavender Extract, Citrus Sinensis, Camellia Sinensis, Mangifera Indica, Leuconostoc Radish Root Ferment Filtrate, Tetrasodium Glutamate Diacetate	skin conditioning, skin protecting, anti-inflammatory effects, soothing effect
Ecklonia cava extract	Phaeophyta	*Ecklonia cava* extract	Skin conditioning agent
Eisenia arborea extract	Phaeophyta	Water, Butylene Glycol, **Eisenia Arborea Extract**	Skin conditioning agent
Gracilaria Verrucosa Extract	Rhodophyta	Gracilaria Verrucosa Extract	humectant, skin protecting, producing agar, potential

INCI Name	Type (color)	Ingredient name	INCI Functions
			antiseptic function for human skin
Porphyra Umbilicalis Extract	Rhodophyta	Aqua (and) Lecithin (and) Alcohol (and) Sodium Lactate (and) **Porphyra Umbilicalis Extract** (and) Phenoxyethanol	Skin conditioning agent
Codium Tomentosum Extract	Chlorophyta	Propylene Glycol (and) Aqua (and) **Codium Tomentosu Extract**	skin protecting
Fucus Vesiculosus Extract (bladderwrack)	Phaeophyta	Fucus Vesiculosus Extract	emollient, skin conditioning, smoothing, soothing
Pelvetia canaliculata extract	Phaeophyta	Aqua (and) **Pelvetia Canaliculata Extract**	skin protecting
Caulerpa Racemosa Extract	Chlorophyta	Caulerpa Racemosa Extract	skin conditioning
Furcellaria Lumbricalis Extract	Rhodophyta	**Furcellaria lumbricalis extract** and perna canaliculus extract	skin conditioning
Ulva Lactuca Extract	Chlorophyta	Glycerin (and) Aqua (and) Hydrolyzed **Ulva Lactuca Extract**	skin conditioning, skin protecting
Saccharina Japonica Extract	Phaeophyta	Saccharina Japonica Extract	skin conditioning
Cladosiphon Okamuranus Extract	Phaeophyta	Cladosiphon Okamuranus Extract	skin conditioning
Sargassum Vulgare Extract	Phaeophyta	Water (and) Botryocladia Occidentalis Extract (and) Hypnea Musciformis Extract (and) **Sargassum Vulgare Extract**	skin conditioning

Subtitle: Phaeophyta (brown algae), Chlorophyta (green algae), Rhodophyta (red alga)

When looking for products that contain macroalgae extracts in their composition through the International Nomenclature of Cosmetic Ingredients (INCI), these extracts will be identified in products of the following skincare categories: skin smoothing, viscosity control, skin conditioning, and skin protection. But more than just skin uses, algae extracts are also present in hair care and self-care products.

It is known that macroalgae have been used since the 19th century by Asian women in thalassotherapy, an important economic activity that uses seawater and its products, including algae, as a form of therapy (Charlier and Chaineux, 2009). Therefore, the presence of algae in beauty rituals; boiling, grinding, and applying them to the skin and hair to restore the skin's plumpness and the natural shine of the hair is nothing new. Initially, the algae incorporated into the first products were essentially soaps, shaving creams, shampoos, colorings, tonics, makeup items, foams, and other bath products (CEN). Over the years and with advances in studies, its content in trace elements began to be considered and implemented.

Trace elements are mineral salts, vitamins, and amino acids. All of them are useful for skincare, in addition to skin health, as they are assimilated by skin cells. Because of this, the ponds have become a great source of new materials for incorporation into cosmetic formulations and with the widest possible purposes: toning treatments, moisturizing treatments, and rejuvenating treatments.

It is necessary to understand better what is meant by skin-protecting, viscosity controlling, skin conditioning, and skin smoothing, to understand the important role of algae in cosmetics. When it comes to skin smoothing, there are ingredients believed to be humectants that work by pulling water into the skin and then holding it there are hydrophilic substances. Hydrophilic carbohydrates are the main and abundant constituent of seaweed and have been used in cosmetic formulations, such as moisturizing and thickening agents (Kim et al. 2018). Polysaccharides, large and sometimes branched carbohydrates, can absorb water in the skin, therefore, they are used as moisturizing agents in cosmetology (Fabrowska *et al.*, 2017).

An emollient soothes the skin, filling in cracks. Therefore, emollients are mostly used for irritated, inflamed skin. Among substances with this characteristic, lipids and fatty acids are emollients. In addition, fatty acids can indirectly affect the stimulation of skin hydration and elasticity (Samarakoon and Jeon, 2012). Given this, an ideal emollient should contain a combination of occlusive agents to delay water loss, humectants to increase moisture-holding capacity, and lubricants to reduce friction against the skin (Hon *et al.*, 2018), which is found in seaweed extracts, such as in *Botryocladia occidentalis* extract.

Viscosity is a rheological parameter, which is the property of the liquid to flow, slide or flow on a surface, therefore it represents the resistance to deformation caused by any tension, for example, the application of a cream (Brummer and Godersky, 1999). According to the INCI, viscosity controlling is the official function name for thickeners, whose ingredients help thicken products, so they form a pleasant gel, serum, or moisturizer texture. Macroalgae are natural thickeners, they stabilize emulsions and even help with the effects of their bioactive properties, such as *Ahnfeltiopsis concinna* extract and *Chondrus crispus* extract. Regarding the skin, with the advancement of aging, a cycle of loss of elasticity and increase in viscosity begins. Therefore, skin hydration through cosmetic and dermatological products can reduce the appearance of aging effects and momentarily improve skin elasticity.

Skin conditioning products are designed to reduce fine lines, hyperpigmentation, age spots, skin laxity, and all of which help improve skin. There are different types of products that include cleansers, topical vitamins, antioxidant products, and retinol products. This class of products can be seen in moisturizers, exfoliants, and different emulsions (Ferreira *et al.*, 2021). This includes the antioxidants present in the different macroalgae extracts used, as well as the other trace elements they contain.

When it comes to skin protectors, algae are a deposit of photoprotective substances, something that can be noticed in the database developed by Gröniger et al. (2000). Substances such as mycosporin-like amino acids (MAAs), sulfated polysaccharides, carotenoids, and polyphenols can be used for photoprotection and provide the skin with adequate protection against ultraviolet B (UVB) and ultraviolet A (UVA) induced photodamage (Pangestuti *et al.*, 2018).

It is interesting to note that in addition to these macroalgae substances already established in studies with activities of interest for cosmetological application, there are more substances of industrial interest in macroalgae extracts than just these. These same extracts can have more activities such as antibacterial peptides (Beaulieu *et al.*, 2015), antifungal (Tyskiewicz *et al.*, 2019) and even antiviral (Polo and Chow, 2022) that can be used in skincare products as preservatives and bioactive compounds, and their use can even eliminate or even replace synthetic products, validating the safety of the final product with equal accuracy.

Nevertheless, the extraction process must be selected so that these compounds are not wasted during the process of obtaining but rather used. Herewith, green processing emerges, which is the ideal choice to obtain improvements in the algae extraction process, as well as in aspects related to the economy in various directions of production, one of them being the reduction of energy consumption, and the transformation of waste into by-products.

5 PRODUCTION OF MACROALGAE INGREDIENTS WITH GREEN TECHNOLOGIES

Choosing which extraction method for marine natural products will be used is the first step and one of the most important to obtaining the compounds of interest. It is known that the most traditional products obtained by macroalgae are polysaccharides, often through high-temperature and alkaline extraction methods, which need aggressive chemical reagents, high energy, and expensive time consumption. Despite the recent technological advances (new techniques and protocols) that enable greener and more efficient extractions, there are still investments in the improvement of traditional methods (**Table 3**).

Table 3. Representative International Patent Applications regarding the preparation of polysaccharides (International Patent Classification [IPC] main group: C08B 037/00) from seaweeds (2002 to 2022).

Polysaccharide (Phycocolloid)	**Patent number**	**Priority date**	**Brief description of the polysaccharides' preparation methods**
Non-specific	WO2021133148	2019/12/27	The present invention provides a method for separating polysaccharides from a seaweed and polysaccharides obtained by the method comprising: a pretreatment step of aging a seaweed at 20-50°C and extracting same with a solvent to remove salts and color materials; a step of extracting, with hot water, the seaweed from which salts and color materials have been removed; a step of separating the hot-water extracted seaweed according to size; and a step of purifying the seaweed separated according to size, at 40-60 °C.

Polysaccharide (Phycocolloid)	**Patent number**	**Priority date**	**Brief description of the polysaccharides' preparation methods**
Agar and Agarose	WO2010109289	2009/03/24	The present invention relates to a more convenient and energy efficient process for the preparation of agarose from Gracilaria and Gelidiella spp., more particularly *Gracilaria dura* and *Gelidella acerosa* from Indian waters, said process comprising steps of pretreating the dry seaweed with alkali, rinsing the pretreated seaweed until the washing shows a pH ranging between 7 and 9, adding water, autoclaving to obtain extractive, centrifuging hot seaweed extractive, then treating the clear hot extractive with surface active chemicals to induce precipitation of agarose, centrifuging the mass to remove the adhering liquid, rinsing the centrifuged mass with water to remove the surface active chemical, preparing a hot sol of the agarose mass in minimum quantity of water, re- precipitating the agarose with iso-propanol to achieve a product having dispersibility while preparing gel, and demonstrating that the said gel in DNA gel electrophoresis studies shows performance equal to that of gel obtained through more conventional process of agarose preparation from the same seaweed extractives as also to gel prepared from commercial benchmark.

Polysaccharide (Phycocolloid)	**Patent number**	**Priority date**	**Brief description of the polysaccharides' preparation methods**
Agar and Carragenan	WO2015102021	2013/12/30	The present invention provides an integrated process for the recovery of a spectrum of commercially valuable products such as agar, cellulose, lipids, pigments and a liquid rich in minerals of agricultural importance directly from fresh seaweed without employing any catalyst driven *in situ* chemical conversions. Also, the solvents used during lipid extraction were shown to be used for three cycles without affecting the yield and quality of successive products. Furthermore, this new process is highly efficient and utilizes total seaweed raw material without any leftover biomass as solid waste.
Carragenan	WO2012123422	2011/03/11	The present invention relates to a method for processing fresh seaweed, to the processed seaweed and to the use of the processed seaweed components in the food sector, in the pharmaceutical sector, as food supplements, for cosmetics and also in animal husbandry as feedstuff and the products which are produced by the method according to the invention.

Polysaccharide (Phycocolloid)	Patent number	Priority date	Brief description of the polysaccharides' preparation methods
Alginates	WO2022139115	2020/12/22	The present invention is to increase production efficiency and decrease production cost of alginic acid and fucoidan. According to the present invention the method comprises the steps of: separating a mixture including ground sea algae, water, and an organic acid into a primary solid and liquid extraction; adding calcium chloride to the separate liquid to aggregate a secondary solid; separating the liquid having the secondary solid aggregated therein into the secondary solid and residual liquid; extracting fucoidan from the residual liquid; and extracting alginic acid from the primary and the secondary solid.
	WO2021090023	2019/11/07	The present invention relates to a method of processing macroalgae in which superheated solvent (water or alcohol [methanol, ethanol, or propanol] or water/alcohol mixtures) is used in an initial pretreatment step (temperature range: 101^{o}C to 150^{o}C; pressure range: 105 kPa to 500 kPa). The polysaccharide extraction is carried out up over 24h in an alkali solution (sodium hydroxide, potassium hydroxide, calcium hydroxide, magnesium hydroxide or sodium carbonate). To precipitate alginate from the previous solution, the alginate composition can be contacted with acid, calcium salt, or an anti-solvent.

Search terms in WIPO IP Portal (142 results) CTR:WO AND PD:[01.01.2002 TO "*"] AND IC_EX:C08B37/00 AND (alga OR seaweed), where: CTR = Country; PD = Priority Date; IC_EX = Exact IPC Code. https://patentscope.wipo.int/search/en/search.jsf

These greener technologies improve yields, minimize solvent waste, save time and energy, and facilitate automation. Some examples include supercritical CO2 extraction, pressurized liquid extraction, subcritical water extraction, and microwave-assisted extraction (Soares *et al.* 2021). These green technologies demand using renewable vegetable sources as macroalgae and developing processes with less use of petroleum-based solvents and even replace them. Finally, reduce costs by reducing time and steps, while optimizing operations, and transforming waste into co-products or by-products (Falkenberg et al. 2019).

Table 4. Brief description of green extraction techniques.

Technology	**Summary of the technique**	**Ref**
Supercritical CO_2 Extraction (CO_2-SFE)	● It is an extraction method that uses CO_2, a generally recognized as safe (GRAS) solvent, in its supercritical state (temperature over 31.1 ^oC, and pressure over 74 bar). The addition of a co-solvent is a strategy to change the extraction polarity. ● While in the extraction process, the solvent flows continuously through the raw material, and an in-line step separates the extract from the solvent that recirculates in the system. Once using multiple separators, the extract may be fractionated into fractions with different chemical compositions. ● The outputs of the process are solvent free non-polar total extracts or fractions, and an exhausted raw material that can be used in a downstream process. It is a zero-waste process.	(Prado *et al.*, 2014)
Pressurized Liquid Extraction (PLE)	● It is an extraction method that enables using solvents in a liquid state even above their atmospheric boiling point. The process often ranges from room temperature to 200 ^oC and pressures between 3.5 and 20 MPa. ● In this process, ethanol or ethanol-water mixture can be used as green solvents. Some works show that the extraction efficiency may increase in a dual solvent mixture. It happens because of complementary effects of both solvents, *i.e.*, while one improves the chemical compound solubility the other enhances its desorption from the raw material matrix. ● In the extraction process (dynamic or static), the solvent flows through the raw material to extract the chemical compounds of interest. Depending on the extraction temperature, the extract flows into a cooling unit to lose its heat to be collected.	(Mustafa and Turner, 2011)

Technology	**Summary of the technique**	**Ref**
Subcritical Water Extraction (SWE)	● It is an extraction method that uses water in its subcritical state (temperature between 100 ^{o}C and 374 ^{o}C, and pressure between 10 and 221 bar) as a solvent. ● In this process, when the water temperature (most important factor) and pressure increases, its polarity decreases. Also, subcritical water has better penetration into the raw material matrix due to its low viscosity and high diffusivity. In this manner, depending on the extraction's parameters, polar or non-polar compounds can be extracted. ● In the extraction process (dynamic or static), the solvent flows through the raw material to extract the chemical compounds of interest, then this hot extract flows into a cooling unit to lose its heat and be collected.	(Gbashi *et al.*, 2017)
Microwave-Assisted Extraction (MAE)	● It is an extraction method that enables using water and ethanol as green solvents. The process temperature is a function of time and power (watts), and the high pressure and temperature are associated to fast and efficient extraction. The extraction process can run in closed (sealed vessels) or opened systems that operate above or under atmospheric pressures, respectively. ● MAE in closed system advantages are fast and efficient extractions and low solvent consumption. Its disadvantages are low biomass processing throughput and is often associated to loss of volatile compounds due to high pressure and temperature. ● MAE in opened system advantages are fast extractions, high sample throughput, the possibility to use higher ratio solvent/feed (associated to higher efficiency) and is suitable for extraction of thermolabile compounds. Its disadvantages are lower extraction efficiency and higher oxidation of compounds comparatively to the closed system.	(Chan *et al.*, 2011; Pinela *et al.*, 2016; Alara *et al.*, 2021)

5.1 Supercritical CO_2 Extraction (CO_2-SFE)

Studies performed with macroalgae as raw material for CO_2-SFE proved of interest to obtain antioxidant extracts (Table 4). It is relevant because this extraction method is a green alternative to petrochemical solvents (*e.g.*, hexane) and less energy and time-consuming than distillation. Currently, a few studies have evaluated the use of macroalgae as renewable sources for CO_2-SFE, mainly from brown species. Most of these studies showed the possibility of recovering antioxidants (*e.g.*, carotenoids and phenolics) from the algal biomass and that the use of co-solvents and often high pressures ($\geq$300 bar) and temperature ($\geq$50 ^oC) favor better global extraction yield.

Ktari *et al*. (2021) compared the differences between solvent extraction (methanol) and CO_2-subcritical and CO_2-SFE extractions from the brown algae *Dictyopteris polypodioides* in terms of fucoxanthin (FX), and total phenolic (TP) contents. This study showed that subcritical extraction (CO_2-liquid at 25 ^oC, 400 bar) and CO_2-SFE at mild-temperature (40 ^oC, 400 bar) had similar extraction yield and recovery about 12% of FX. However, these conditions were more selective to extract TP (~2.2-fold higher than methanol extraction). After increasing the temperature to 60 ^oC, the authors evaluated different pressures (300, 400, and 500 bar) that resulted in a better FX recovery than the previous CO_2 tested conditions, although lower than methanol extraction (up to ~59%). Concerning TP content, the results at 60 ^oC were significantly higher than the methanol extraction, and 500 bar showed the best results for selectivity (~2.5-fold) and yield (~2-fold). It is interesting to notice that the CO_2-liquid extraction (25 ^oC, 400 bar) of another brown alga *Undaria pinnatifida* showed better FX extraction selectivity than higher temperatures (Quitain *et al.*, 2013), an oppositive result to *D. polypodioides* even though sharing matrix similarities (*e.g.*, alginic acids and fucoidan).

In addition to using a myriad of extraction parameters combination (*e.g.*, pressure, temperature, solvent-to-feed ratio) to selectively extract some chemical classes, there is the strategy of employing co-solvents to modify the extraction fluid polarity and density. Ospina *et al.* (2017) investigated the effect of pressure (100, 200, and 300 bar), temperature (40, 50, and 60 ºC), and co-solvent (2, 5, and 8% ethanol) on the extraction yield, antioxidant activity, and total carotenoid (TC) and TP from the red alga *Gracilaria mammillaris*. In the study, the Pareto chart demonstrated that ethanol concentration followed by pressure were variables that positively correlated with TP content and extraction yield. In the case of TC content, the parameter pressure was the most relevant factor. Moreover, despite not being as efficient as the commercial antioxidants used as control (TBHQ, BHT, and gallic acid), the results demonstrated that all extracts had protecting capacity against the lipid peroxidation of the tested edible oil. Rozo *et al.* (2019) showed comparable results for another red alga *Hypnea musciformis* using similar experimental conditions. In addition, they proved the presence of the antioxidant compounds phloretin and (-)-epicatechin that are of great interest for the cosmetic industry. Saravana *et al.* (2017) studied how the co-solvents sunflower oil (SFO), soybean oil, canola oil, ethanol, and water impact the extraction of TC, FX, and phlorotannin (PT) from *Saccharina japonica*. The results showed that 300 bar, 55 °C, and 2.0% co-solvent were optimal conditions for high content of TC, FX, and PT for the most modifiers. Among the co-solvents, water had the best performance for PT, while SFO was more efficient in recovery TC and FX. The authors also showed that the strategy CO2-SFE + SFO yields rich content of fatty acids, high antioxidant activity, and high oil stability.

5.2 Pressurized Liquid Extraction (PLE)

PLE is another timesaving and solvent-reducing approach. It can work as a primary extraction technology and a downstream process from other industrial techniques like CO_2-SFE (Fitzpatrick *et al.*, 2000). Indeed, some works have demonstrated the feasibility of this strategy for renewable raw materials such as turmeric rhizome (Silva *et al.*, 2018) and annatto seeds (Alcazar-Alay *et al.*, 2017), showing the possibility of working in a biorefinery strategy with the zero-waste practice because the "waste biomass" is a commercial value carbohydrate-rich co-product. As a primary step or in a zero-waste biorefinery concept, PLE is a viable strategy for macroalgae biomass valorization (Table 4).

Fayad *et al.* (2017) demonstrated that extracts from the brown macroalga *Padina pavonica* obtained through green technologies have anti-skin aging activity. In the PLE process, the authors mixed the biomass with diatomaceous earth (50:50 w/w) and ran two extraction cycles with water at 60 ^oC and 150 bar. The extract recovered from PLE inhibited 100% hyaluronidase activity (HAase, EC 3.2.1.35) at concentrations similar to phlorotannin (polyphenolic) fractions from *Eisenia bicyclis* extracted with solvents (Shibata *et al.*, 2002). Indeed, phenolic compounds are efficiently extracted through PLE, as demonstrated for the green macroalga *Codium fragile [ethanol:water (80:20), 100 ^oC, and 68.9 bar]* and red macroalga *Gracilaria gracilaris [water, 120 ^oC, and 103 bar]* (Heffernan *et al.*, 2014). However, other inexpensive technologies with GRAS solvents may retrieve better results than PLE, as demonstrated with *C. fragile*. In this case, it is pivotal to consider the efficiency and the scalability of the chosen technology in an economic feasibility evaluation. While the solvent-liquid extraction of the green macroalga had an extraction time of 24 h, the PLE extraction protocol was 25 min. Also, PLE is associated with low solvent use and, consequently, less time to evaporate the solvent in downstream processes.

Another central aspect to consider is the global strategy of the industry. PLE is a multifunctional technology and a green alternative to organic solvents. Otero et al. (2019) optimized two protocols to extract fatty acids from the brown alga *Laminaria ochroleuca*. By using ethanol at 120 ^oC and 100 bar, the extraction favored the presence of unsaturated fatty acids (USFA) over saturated fatty acids (SFA), *i.e.*, USFA/SFA was 1.24. Otherwise, running PLE with ethanol:water (2:1) at 120 ^oC and 100 bar yielded an extract with a higher proportion of SFA, *i.e.*, USFA/SFA was 0.79. Even though the first protocol favored USFA extraction, the global extraction yield was about 3-times lower than the ethanol:water extraction. Therefore, the absolute content of the USFA yield was higher with the second protocol (USFA per dw), *i.e.*, about 2.26-fold superior. Then, by applying one of the well-known downstream protocols for USFA and SFA separation (Haraldsson, 1984), ethanol:water extraction favors the best use of the algal biomass.

Moreover, some studies have demonstrated the technical feasibility of using PLE to extract polysaccharides (PS). Dobrincic *et al.* (2021) tested the efficiency of PLE on the waste biomass (a by-product from solvent extraction) of the brown algae *Cystoseira barbata* and *Fucus virsoides* and compared the results with other technologies. The optimized extraction was 0.1 M H_2SO_4 for two cycles of 15 min at 105 ^oC and 103 bar and a downstream process for PS precipitation. Compared to conventional extraction, PLE reduced the solvent usage and extraction time (from 3 h to 30 min), having a similar or higher PS content for *C. barbata* and *F. virsoides*, respectively. In addition, PS had a higher proportion of sulfate group in both algae. In another study, Diop *et al. (2022)* showed the technical feasibility of an upcycling approach by extracting agar from the red alga *Gelidium sesquipedale* collected from the waste stream of a primary industrial phycocolloid extraction. In this study, the agar recovery and its physicochemical characteristics were ideal in PLE with water at 100 ^oC and 10.13 bar. Also, the authors demonstrated that different temperatures, pressures, algae-to-water ratio, and extraction times tested affected gel strength, hysteresis, hardness, cohesiveness, gumminess, adhesiveness, and springiness.

5.3 Subcritical Water Extraction (SWE)

Subcritical water extraction (SWE) is a modern technique that use temperature variations to selectively extract polar and non-polar compounds from raw materials (Alboofetileh et al. 2019). This allows subcritical water to carry out selective extractions, such as the extraction of polar compounds at lower temperatures and less polar compounds at higher temperatures, useful both for extraction and hydrolysis of proteins and other fractions (lipids, carbohydrates, phenolics). However, proper selection of operating conditions is necessary to maximize extraction yield and avoid degradation to monomer units and decomposition products (Cheng et al. 2021). It reveals that the practice of this technique may vary according to the structural characteristics of the raw material and solubility of the target compound.

Pangestuti et al. (2019) used this technique to hydrolyze *Hypena musciformis* and obtain antioxidants. Thus, a material with good antioxidant activity can be recovered at 210 °C and sugar and emulsion formation at <180 °C were obtained, which demonstrates the possibility to use this process and macroalga for more of a cosmetic application. Furthermore, *Caulerpa acemose* (sea grapes) and *Ulva lactuca* (sea lettuce) were submitted to SCWE and analyzed for their nutritional values and the recovery of bioactive compounds. From there, a significantly higher extraction yield was seen with this technique in addition to providing higher protein, sugar, total phenolic (TPC), saponin (TSC), flavonoid contents (TFC), and antioxidant activities. Cytotoxic assays also revealed that the hydrolysates of these macroalgae did not show any toxic effect on monocyte/macrophage-like cells at certain concentrations tested, suggesting that both hydrolysates were safe and non-toxic for application in food, cosmeceuticals, and nutraceuticals.

Interestingly, Flórez-Fernández. and Domínguez (2019) decided to use this method to extract alginate, fucose-rich sulfated polysaccharides, and phlorotannins from *Sargassum* sp. And noticed that the valorization of the alginate fraction obtained was more efficient to the biorefinery concept applied to this macroalga to produce components with interesting biological properties. In addition to other studies (Zhang and Thomsen 2021) that involved this method to obtain greater energy efficiency in several stages of the process of a biorefinery, as well as to obtain biomolecules of interest during the production scale.

5.4 Microwave-Assisted Extraction (MAE)

Microwave-assisted extraction (MAE) is a technique that extraction occurs as a result of changes in cell structure caused by electromagnetic waves. Using microwaves to heat solvents and plant tissues increases extraction kinetics and several advantages are gained over traditional solvent extraction, including shorter extraction times, higher extraction rates, lower costs, less solvent use, moderately high recoveries, and minimal sample preparations (Beoletto et al. 2016). As shown in table 5, sulfated polysaccharides (fucoidan) from the brown seaweed *Ascophyllum nodosum* were extracted by this technology, and the optimal yield of this polysaccharide was 16.08%, from 120 °C for 15 min of extraction, all fucoidans exhibited antioxidant activities measured by the elimination and reduction of DPPH, among which the fucoidan extracted at 90 °C was the highest (Yuan and Macquarrie 2015). This study shows that MAE is an efficient technology to extract sulfated polysaccharides from seaweed, and *Ascophyllum nodosum* can potentially be a resource for natural antioxidants. Not to mention that this same method extracted considerable yields of carrageenan from *Hypnea musciformis* during MAE extraction, and the hybrid кappa/iota carrageenan obtained by this method is comparable to that extracted by the conventional technique (Vázquez-Delfín et al. 2014), this just reveals that macroalgae can be scanned for as many applications as possible in the same product.

Table 5. Production of sustainable ingredients from some macroalgae through green technologies.

Technology	**Species of seaweed, color**	**Highlights**	**Reference**
Supercritical CO_2 Extraction (CO_2-SFE)	*Dictyopteris polypodioides*, brown	The extraction with CO_2 at 60 ºC resulted in higher global extraction yield and fucoxanthin content than lower temperatures but were not affected by the tested pressures. Total phenolic content and DPPH antiradical-scavenging capacity results showed the same behavior.	(Ktari *et al.*, 2021)
	Gracilaria mammillaris, red	The extraction operated with CO_2 + ethanol (as a co-solvent). The co-solvent concentration and pressure positively correlated with global extraction yield and the concentration of total phenolics extraction, while pressure was the most relevant factor for total carotenoid (TC) extraction. The extracts reduced the lipid oxidation of the tested edible oil, although they were not as effective as the reference antioxidants.	(Ospina *et al.*, 2017)
	Hypnea musciformis, red	Different conditions of extraction with CO_2 resulted in extracts with antioxidant activities, and the proportion of ethanol (co-solvent) directly correlated to the increase in antioxidant activity (ABTS) and protection against lipid peroxidation. Phloretin and (-)-epicatechin were phenolics found in the study.	(Rozo *et al.*, 2019)

Technology	**Species of seaweed, color**	**Highlights**	**Reference**
	Saccharina japonica, brown	The use of CO_2 + sunflower oil (as co-solvent) favored the extraction of total carotenoid and fucoxanthin, and yield rich content of fat acids, high antioxidant activity, and high oil stability; CO_2 + water (as co-solvent) was more efficient for extraction of phlorotannin.	(Saravana *et al*., 2017)
	Undaria pinnatifida, brown	The use of CO_2 extraction to recover fucoxanthin from seaweeds discharged into the environment due to non-attendance of food quality standards. In subcritical conditions (400 bar, 25 ^oC), the extraction was more selective, while supercritical conditions favored high fucoxanthin recovery.	(Quitain *et al*., 2013)
Pressurized Liquid Extraction (PLE)	*Codium fragile*, green	The extraction with ethanol:water (80:20) at 100 ^oC and 68.9 bar was more selective to recover TP than other solvents tested with PLE, despite having lower extraction yield than the protocol with water at 100 ^oC and 103 bar. Also, the extracts had higher antioxidant activity. However, most PLE protocols had lower performance than solid-liquid extraction (SLE).	(Heffernan *et al*., 2014)

Technology	Species of seaweed, color	Highlights	Reference
	Cystoseira barbata, brown	The pre-treatment of the raw material was the seaweed maceration with (1st step) acetone (18 h, at room temperature) and (2nd step) ethanol (4 h, at 70 ºC). Distilled water and H_2SO_4 were the solvents tested at constant pressure under different temperatures to extract polysaccharides (PS). The optimized protocol reduced the extraction time to 30 min (3 h for conventional extraction) and resulted in similar PS extraction yield. Furthermore, the PS presented higher sulfate group proportion and lower uronic acid content than PS from conventional extraction, although the lower antioxidant activities.	(Dobrincic *et al.*, 2021)
	Fucus virsoides, brown	The pre-treatment of the raw material was the seaweed maceration with (1st step) acetone (18 h, at room temperature) and (2nd step) ethanol (4 h, at 70 ºC). Distilled water and H_2SO_4 were the solvents tested at constant pressure under different temperatures to extract PS. The optimized protocol reduced the extraction time to 30 min (3 h for conventional extraction) with a higher PS extraction yield. Likewise, the PS had higher sulfate group proportion and fucose content while lower uronic acid content and antioxidant activities than PS from conventional extraction.	(Dobrincic *et al.*, 2021)

Technology	Species of seaweed, color	Highlights	Reference
	Gelidium sesquipedale, red	In an upcycling approach (algae from a waste stream of a primary industrial phycocolloid), the agar extraction was possible with water at 100 ºC and 10.13 bar. It showed that different temperatures, pressures, algae-to-water ratio, and extraction times tested affected gel strength, hysteresis, hardness, cohesiveness, gumminess, adhesiveness, and springiness.	(Diop *et al.*, 2022)
	Gracilaria gracilis, red	Extraction with water at 120 ºC and 103 bar was the protocol with the highest extraction yield. Statistically, there was no difference among the protocols tested for PLE regarding TP content, DPPH scavenging activity, and antioxidant activity. The extraction yield of PLE with water was like most SLE protocols, but the extract presented lower TP recovery, DPPH scavenging activity, and antioxidant activity.	(Heffernan *et al.*, 2014)

Technology	Species of seaweed, color	Highlights	Reference
	Laminaria ochroleuca, brown	The use of ethanol at 120 °C and 100 bar was the optimized protocol that favored the extraction of unsaturated fatty acids (USFA), while ethanol:water (2:1) favored the extraction of saturated fatty acids (SFA). However, the absolute content of USFA was ~2.26-fold superior with ethanol:water because of the higher global extraction yield (~3-fold) than ethanol. In addition, ethanol:water was more efficient recovering TP content.	(Otero *et al.*, 2019)
	Padina pavonica, brown	The optimum extraction condition was 2 extraction cycles with water at 60 °C and 150 bar, in which the extract inhibited 100% of the hyaluronidase activity.	(Fayad *et al.*, 2017)
Subcritical Water Extraction (SWE)	*Caulerpa racemosa*, green	Processes tested at different temperatures (110 to 230 ^{o}C with 40 ^{o}C increments) and 50 to 70 bar yielded up to ~60% (dw basis) of acidic hydrolysate. 190 ^{o}C was the optimal temperature regarding global yield. At 230 ^{o}C, the extract had stronger ultraviolet (UV)-B absorption, higher total protein, TP, flavonoid (TF), and saponin (TS) contents, and antioxidant activities.	(Pangestuti, Haq, *et al.*, 2021)

Technology	Species of seaweed, color	Highlights	Reference
	Codium tomentosum, green	The multi-step isobaric process (100 bar, temperature range 20 to 250 ºC) yields up to 51.4% of cumulative extract. The increase in temperature augmented TP and TF contents, but phlorotannin content was higher at low temperatures. It is noteworthy that free amino groups positively correlate to higher temperatures and that reducing sugar contents increased comparatively to the raw material indicating the presence of hydrolysis.	(Soares *et al.*, 2021)
	Hypnea musciformis, red	The hydrolysis efficiencies ranged from 61.37 to 81.23% at different solvent-to-feed (S/F) ratios (50:1, 100:1, and 150:1) and temperatures (120 to 270 ºC with 30 ºC increments) that yielded acidic extracts. Regarding the global yield, the tested temperatures over 210 ºC showed higher hydrolysis efficiencies and were not affected by the S/F tested. The combination of 210 ºC and S/F 50:1 was the optimal condition to obtain high total protein, TP, and TF contents that positively correlate to the evaluated antioxidant activities.	(Pangestuti *et al.*, 2019)

Technology	Species of seaweed, color	Highlights	Reference
	Saccharina japonica, brown	The input raw material for the tests was a CO_2 supercritical de-oiled seaweed, and SWE was a upstream step for the alginate and fucoidan extraction. The procedures ran at different temperatures (100, 125, and 150 ^oC), pressures (10, 30, and 50 C), deep eutectic solvents mixture with water (30, 40, and 50%), and S/F (30:1, 40:1, and 50:1). According to the statistical model, the optimal parameters combination was 150 ^oC, 19.85 bar, 30% of choline chloride:glycerol (1:2) in water, and S/F 36.81:1 that yielded 28.12% and 14.93% of functional alginate and fucoidan, respectively. However, they presented lower antioxidant activities compared to commercial standards.	(Saravana *et al.*, 2018)
	Sargassum thunbergii, brown	The processes tested at different temperatures (120 to 240 ^oC with 30 ^oC increments), isobaric at 30 bar, and S/F 20:1 reached up to ~80% of extraction efficiency (EE). 180 ^oC presented a relevant EE (70.33%), and the maximum values observed for total phlorotannin positively correlated to the antioxidant activities tested. Also, some phenolic compounds concentrations were evaluated and ranked as follows: pyrogallol > p-coumaric acid > chlorogenic acid = protocatechuic acid > gallic acid > syringic acid.	(Park *et al.*, 2022)

Technology	**Species of seaweed, color**	**Highlights**	**Reference**
	Ulva lactuca, green	Processes tested at different temperatures (110 to 230 ºC with 40 ºC increments) and 50 to 70 bar yielded up to ~45% (dw basis) of acidic hydrolysate. 190 ºC was the optimal temperature regarding global yield. At 230 ºC, the extract had higher total protein, TP, TF, and TS content and antioxidant activities. UV-B absorption was strong and similar for extracts obtained at 190 and 230 ºC.	(Pangestuti, Haq, *et al.*, 2021)
Microwave-Assisted Extraction (MAE)	*Cystoseira barbata*, brown	The pre-treatment of the raw material was the seaweed maceration with (1st step) acetone (18 h, at room temperature) and (2nd step) ethanol (4 h, at 70 ºC). Distilled water, 0.1 M HCl, and 0.1 M H2SO4 were the solvents tested (S/F 30:1) at different temperatures (60, 80, and 100 ºC) and extractions times (10, 20, and 30 min) to extract polysaccharides (PS). The optimized protocol (0.1 M H_2SO_4 at 80 ºC) reduced the extraction time to 10 min [3 h for conventional extraction (CE)] and yielded ~15% of PS. The PS had a higher sulfate group proportion and a lower uronic acid content than PS extracted with CE. In addition, the extract had a higher antioxidant capacity although lower radical scavenging capacity than the CE.	(Dobrincic *et al.*, 2021)

Technology	Species of seaweed, color	Highlights	Reference
	Fucus virsoides, brown	The pre-treatment of the raw material was the seaweed maceration with (1st step) acetone (18 h, at room temperature) and (2nd step) ethanol (4 h, at 70 ºC). Distilled water, 0.1 M HCl, and 0.1 M H_2SO_4 were the solvents tested (S/F 30:1) at different temperatures (60, 80, and 100 ºC) and extractions times (10, 20, and 30 min.) to extract polysaccharides (PS). The optimized protocol (0.1 M H_2SO_4 at 80 ºC) reduced the extraction time to 10 min [3 h for conventional extraction (CE)] and yielded ~20% of PS. The PS had a higher sulfate group proportion and a lower uronic acid content than PS extracted with CE. In addition, the extract had a higher antioxidant capacity and a similar radical scavenging capacity than the CE.	(Dobrincic *et al.*, 2021)
	Gelidium amansii, red	MAE was the first step for producing cellulose microfibrils. Distilled water, 1% NaOH, and 1% H_2SO_4 were the solvents tested (S/F 10:1) at different temperatures (100 to 180 ºC) to favor cellulose extraction over the agar. The optimized protocol was distilled water for 10 min at 180 ºC. The derived cellulose microfibrils exhibited anti-inflammatory activity. Also, it might be an active functional nanomaterial for cosmetics.	(Jang *et al.*, 2021)

Technology	Species of seaweed, color	Highlights	Reference
	Padina pavonica, brown	The optimum extraction condition was water at 60 °C and 1,000 watts, in which the extract inhibited 100% of the hyaluronidase activity.	(Fayad *et al.*, 2017)
	Sargassum swartzii, brown	The combination of different ethanol concentrations (20 to 96% with 20 ºC increments), S/F (15:1 to 40:1 with 5:1 increments), microwave power (80 to 720 W with 160 W increments), and extractions times (15 to 90 min with 15 min increments) yielded phlorotannin extracts with antioxidant activities. The optimized protocol determined by a statistical model was 65 min, ethanol 52%, microwave power 613 W, and S/F 33:1.	(Toan *et al.*, 2021)
	Ulva lactuca, green	Extraction with ethanol 70% at 90 ºC (1,500 W) and S/F 15:1 for 30 min yielded ~22% of an extract with significant TP content and antioxidant activity. The dermo-cosmetic preparations (a gel and an emulsion) with the extract were thermal and mechanically stable. Also, these formulations were efficient in the active skin permeation and cutaneous retention test.	(Grillo *et al.*, 2021)

Technology	Species of seaweed, color	Highlights	Reference
	Ulva pertusa, green	The pre-treatment of the raw material consisted of seaweed maceration (S/F 4:1) with ethanol 80% (2 h, at 85 ºC) for pigment removal, followed by centrifugation and drying. Distilled water was the solvent used for the tests with different extraction times (30, 45, and 60 min), power (500, 600, and 700 W), S/F (40:1, 55:1, and 70:1), and pH (5, 6, and 7) that yielded up to ~41% of ulvan extract that showed antioxidant activities. Also, it upregulated the expression and enhanced the activity of the antioxidant enzymes superoxide dismutase and catalase. The optimized protocol was distilled water for ~44 min, 600 W, S/F 55.45, and pH 6.57.	(Le *et al.*, 2019)

6 SAFETY OF ALGAE EXTRACTS IN COSMETICS

Before reaching the shelves, the safety of these products based on algae must be effective, and not only the safety of the consumer must be considered, but also the safety of the environment that will be impacted by the product of algal origin. This issue considers the current legislation regarding production and preparation.

Since, in growing as an industry, the process of safety and effectiveness is necessary for scandals like the Morhange talc issue in 1973 to no longer occur. There have been deaths that are due to Morhange's talc and the presence of hexachlorophene, a potent bactericide, at excessive levels. The French government reacted immediately and withdrew all boxes of talc powder from the market. At the time, the toxicity of hexachlorophene was not known to the general public. An unpublished study of guinea pigs in 1939 showed that about ten of them died three days after ingestion of the product (Dumoulin, 1985). At the time, the product did not present any particular hazard in its nominal composition. The company Morhange, which marketed the product, had neither the equipment nor the competent personnel to carry out the compliance checks, nor the packaging company. The legislation did not classify hexachlorophene among dangerous substances, a deficiency then filled in September 1972 and September 1973 (Coiffard and Couteai, 2017). Not to mention the case of Lush Lure in 1933 and its mascara that promised women the appearance permanently made up with aniline dye on the eyelashes. Regrettably, some women have been blinded by the presence of the chemical p-phenylenediamine. This incident was directly linked to the passage of the Act of 1938, in the United States of America, introduced by the Food and Drug Administration (FDA), revealing the need for more regulation (Eschner, 2017). These examples and a few others made health legislation more serious for cosmetics around the world, including concepts and differences, in addition to consumer requirements.

When thinking about plans to better develop policies to deal with this development of safe products, even using products of algal and natural origin, that arise through the increase in conscious consumer demand, one must consider the presence of various international organizations and their guidelines.

Definition of international bodies of standardization
About OECD “The Organization for Economic Co-operation and Development is an international organization that works to build better policy together with governments and citizens, thus setting evidence-based international standards and finding solutions to a range of social, economic, and environmental challenges.”
About ISO “International Organization for Standardization is an independent, non-governmental international organization with a membership of 167 national standards bodies. Through its members, it brings together experts to share knowledge and develop voluntary, consensus-based, market relevant International Standards that support innovation and provide solutions to global challenges.”
About SCCS “The Scientific Committee on Consumer Safety provides Opinions on health and safety risks (chemical, biological, mechanical and other physical risks) of non-food consumer products (e.g. cosmetic products and their ingredients, toys, textiles, clothing, personal care and household products) and services (e.g. tattooing, artificial sun tanning).”

From a cosmetics perspective, the OECD makes Testing Guidelines available which are covered by the OECD Mutual Acceptance of Data (MAD) system and show the results of laboratory tests related to the safety of chemicals that are generated following these Guidelines and the OECD Principles of Good Laboratory Practice. These standards are accepted in all OECD and acceding countries for safety assessment and other uses related to the protection of human health and the environment (OECD, 2022) and some examples can be seen in the Table 6.

Table 6. Some examples of mandatory tests to be done according to the OECD or ISO for cosmetics

Guide	**Briefing description**
ISO 10993-5 (Test for in vitro cytotoxicity)	It describes methods for assessing cytotoxicity *in vitro* and specifies the incubation of cultured cells in contact with a device and/or extracts from a device directly or by diffusion. These methods are designed to determine the biological response of mammalian cells *in vitro* using appropriate biological parameters.
OECD 432 (Test of photocytotoxicity)	It describes an *in vitro* method for evaluation of photocytotoxicity by the relative reduction in the viability of cells exposed to the chemical in the presence versus absence of light.
OECD 439 and ISO 10993-10 (skin irritation test)	They describe *in vitro* procedures that can be used for hazard identification of irritating chemicals (substances and mixtures) following Category 2 of the UN Globally Harmonized System of Classification and Labeling (GHS). The methods are based on the reconstructed human epidermis (RhE), which in its overall design closely mimics the biochemical and physiological properties of the upper parts of human skin and offers key factors for the interpretation of results.
OECD 431 (Test of cutaneous corrosivity)	This method allows the identification of corrosive chemical substances and mixtures, and the identification of non-corrosive substances and mixtures when supported by a weight of evidence determination using other existing information. The test protocol can also indicate the distinction between severe and less severe skin corrosives. This Test Guideline does not require the use of live animals or animal tissue for the assessment of skin corrosivity.
OECD 491 (Test of eye irritation/corrosivity)	It describes an *in vitro* cytotoxicity-based assay that is performed on a confluent

Guide	**Briefing description**
	monolayer of Statens Seruminstitut Rabbit Cornea (SIRC) cells, cultured on a 96-well polycarbonate microplate.
OECD 428 (Test of skin permeation/absorption)	This method provides information on the absorption of a test substance (preferably radiolabelled) applied to the surface of a skin sample that separates the two chambers (a donor chamber and a recipient chamber) of a diffusion cell. Static and flow diffusion cells are both acceptable. Human or animal skin can be used.
OECD 129 (Test of prediction of oral toxicity)	This method is an *in vitro* alternative of animal testing to estimate starting doses for oral systemic toxicity tests.
OECD 442E (Test of skin sensitization)	The present Key Event-based Test Guideline (TG) addresses the human health hazard endpoint of skin sensitization, following exposure to a test chemical. Skin sensitization refers to an allergic response following skin contact with the tested chemical, as defined by the United Nations Globally Harmonized System of Classification and Labelling of Chemicals (UN GHS).
OECD 487 (Test of genotoxicity)	The assay detects the activity of clastogenic and aneugenic test substances in cells that have undergone cell division during or after exposure to the test substance, it is an *in vitro* micronucleus test for the detection of micronuclei in the cytoplasm of interphase cells

In addition to the OECD, there is also the ISO, and its main function in conjunction with the technical committees is to prepare International Standards. For cosmetics some guidelines are intended to guide Good Manufacturing Practices for these products, being ISO 22716:2007 and ISO 16128-1. The ISO 22716:2007 guides documenting and regulating the production, control, storage, and shipping of cosmetic products, without forgetting to take quality management to levels of excellence. And according to ISO 16128-1, to be classified as natural, the product must contain natural ingredients, while for organic certification a minimum percentage of ingredients from organic production is required, and for Resende *et al.* (2021) marine macroalgae in this environment are progressively occupying the place that botanical ingredients have long led the way, with great diversity across multiple categories.

When it comes to algae in this environment, the European Union has the SCCS and its guidance notes for the testing of cosmetic ingredients and safety assessment (NoG). The most recent was the one adopted in March 2021, where to use algae in cosmetic products, common or usual names, variety name, species, genus, and family are recommended, if more than one variety of source from a given source is used species, each must be specified, organoleptic, macroscopic and microscopic assessment, morphological and anatomical description (including genus, if applicable) and a photograph of the alga or part of the alga, natural habitat, and geographic distribution, current sources of the alga, including its location geographical location and whether it is cultivated or harvested in nature, in addition to the description of the preparation process (harvesting, washing, drying, extraction, distillation, destructive distillation, eventual purification, conservation procedures), handling, transport, storage, commercial form: powder, solution, suspension, characteristic elements of the composition (identification of characteristic components, known toxic components (%), physical specifications and chemical, microbiological quality including relevant fungi additional external contamination, preservatives and/or other additives added. Therefore, it is not a simple process and requires several tests for this macroalgae-based product to reach the market shelves.

Furthermore, there is also the presence of Material Safety Data Sheets (MSDS), which disclose a list of hazardous ingredients in a product, their physical and chemical characteristics, their effect on human health, the chemicals with which they may react adversely, precautions handling, the types of measures that can be used for exposure control, emergency and first aid procedures, and methods of containing a spill. This is necessary as each hazard rating needs to be considered in the safety assessment of cosmetic ingredients, particularly when using algae extract in the product. Here, once again, the importance of choosing the extraction technology and the best characterization of that extract and its effects is highlighted. Without considering that, in addition to being a natural product, the use of macroalgae and the process of obtaining it is still biotechnological, and for that, it must also go through steps of verification and safety.

When pondering about environmental safety related to extracts obtained from macroalgae, it should be considered that even the solvent selection stage can lead to greater environmental impacts due to the use of solvents derived from fossils and toxics, even though these are more economical. As rightly pointed out by Zapata-Boada et al. (2021), conventional lipid extraction processes, for example, normally use volatile organic solvents derived from fossil resources, such as hexane, which its toxicity and high losses make it environmentally unfavorable. With that in mind, studies by Tanzi et al. (2012) have already led to a green solution to replace hexane in this type of extraction, which was using terpenes (limonene, pinene, cymene) obtained from renewable raw materials as alternative solvents and obtained similar lipid extraction yields to those obtained with hexane. So, here comes the bottom line of the matter, not only reducing solvent use can be considered “green” in itself but choosing which solvent it will be is also part of development and sustainability in production.

It is worth noting that the MDSD also has a mandatory section in its report on ecological information to assess the environmental impact of the chemical(s) if released into the environment, which is section 12. In addition to having section 13 for disposal considerations and guidance on proper disposal practices, recycling or recovery of the chemical(s) or its container, and safe handling practices. Therefore, all this is necessary to reach the ideal level of suitability, since the extracts obtained through algae, despite being advantageous in several applications, must be safe, so these tests must be carried out.

Related to safety, the mandatory toxicological tests of this seaweed extract are also preceded, which is indicated by the Scientific Committee on Consumer Safety (SCCS), which are pre-clinical tests. These tests are acute systemic toxicity, dermal corrosivity and irritation, skin sensitization, skin absorption/penetration, repeated doses, mutagenicity/genotoxicity, subacute and subchronic toxicity, eye irritation, mucosal irritation, UV radiation-induced toxic effects (phototoxicity, genotoxicity, photoallergy), carcinogenicity, developmental and reproductive toxicity (teratogenicity), toxicokinetics and toxicodynamics. Each test mentioned above, they are based on an OECD guideline, such as skin irritation, which corresponds to OECD 404 as an example. All this is necessary to reach the ideal level of adequacy.

It is worth mentioning here the evolution of animal-free tests, which, in a way, involves the aspect of technological evolution, certainly included in this “green wave” provided by consumer appeal, such as the search for the insertion of natural products. There are alternative methods that, according to Cruelty Free International, are a good substitute for tests on animals, such as in vitro human cell and tissue culture, computer models, and even human volunteers. One of these alternatives is the use of skin models, not only because it is physiologically relevant in drug development, but also because it provides a better prediction of human skin safety, in addition to ethical issues and economic factors. Reconstructed human skin (RHS) is a way to detect the potential for phototoxicity, without testing on animals, and studies such as that by Tavares *et al.* (2020) use this method to evaluate the photoprotective potential of a molecule and its formulation in sunscreen.

This type of RHS and 3D tissue construct are logical follow-up tools to standard '2D' genotoxicity assays as they support more natural cell-cell and cell-matrix interactions and show 'live-like' behavior for key parameters such as cell proliferation and gene expression (Pfuhler *et al.*, 2021). This makes this alternative essential for cosmetology testing and OECD guidelines, in this case, 431 (Reconstructed Human Epidermis Test Method (RHE), for example. Consequently, emerging cosmetics markets require the use of human cell-based testing systems, and in parallel, studies prove the applicability of new organ-on-chip compatible RHS for the assessment of substance effects (Spagolla *et al*., 2020), which only reveals the increasing of studies in 3D fabrics and their technological developments.

7 INDUSTRIAL PERSPECTIVES IN A MACROALGAE BIOREFINERY CONCEPT AND ITS SOCIAL AND ENVIRONMENTAL IMPACT

Macroalgae have different cultivation methods that vary depending on location and algae species. Examples are raft, rope, tube-net, bag-net, longline, tube-net, monocline, bag, tank cultivation, and photobioreactor. In a more complex cultivation system, macroalgae have been evaluated as biofilters in Integrated Multi-Trophic Aquaculture (IMTA) because of their basal trophic level. Recently, Carneiro et al. (2021) showed that the IMTA of shrimp (*Litopenaeus vannamei*) and the red alga *Gracilariopsis tenuifrons* resulted in the biomass increase of macroalga (up to one week) and shrimp. In this sense, the production of high-quality seaweed biomass with minimal nutrient requirements for sustainable cultivation on land for industrial purposes is increasingly encouraged (Kumar et al. 2021).

The supply chain that starts with the source of macroalgae biomass (harvested or cultivated) and passthrough their industrial processing to end up with the final products is of great interest to the Bioeconomy and the Blueconomy. When considering the consumption of the final products in a Circular Regenerative Economy, like cosmetics, macroalgae biorefineries (MABs) are pivotal for reducing the carbon footprint. For example, in a cradle-to-cradle simulation, Seghetta *et al.* (2016) evidenced that 100% of macroalga biomass converted into a protein-rich fish feed, a liquid fertilizer, and ethanol reduces atmospheric CO_2. In this simulation, macroalgae cultivation and soil's carbon retention were the key players in carbon footprint mitigation. Therefore, MABs emerge as a solution for improving the macroalgae biomass use in a zero-waste concept.

According to Saral *et al.* (2022), the biorefinery is a framework or structure in which biomass is optimally used to produce multiple products and aims to be self-sustainable and not harmful to the environment. In this sense, the use of green technologies (see Table 5) is of great interest. In Figure 1 is an illustrative scenario of an integrated MAB based on the combination of the aforementioned green technologies CO_2-SFE, PLE, SWE, and MAE.

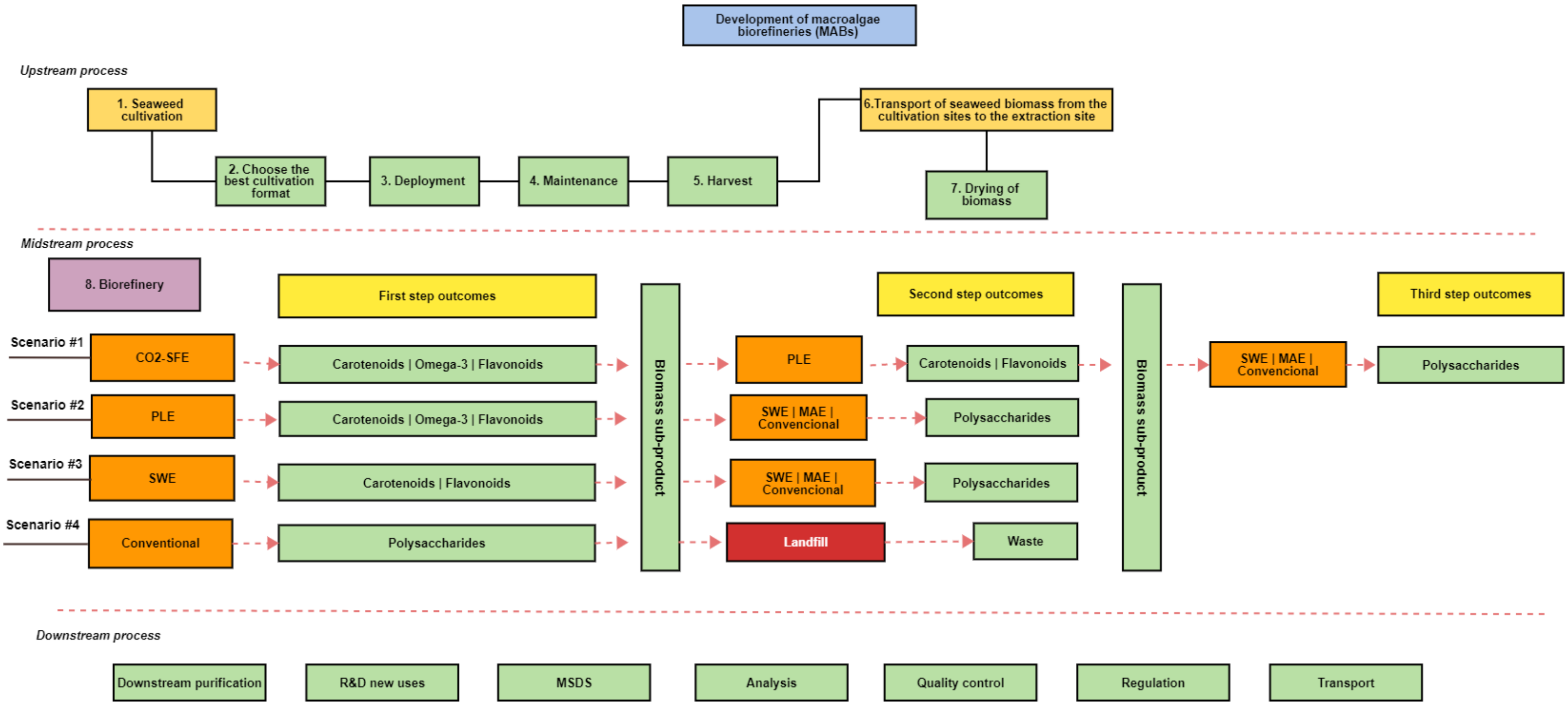

Figure 1. Illustrative scenarios of integrated biorefineries regarding macroalgae biomass processing with green technologies.

As a first step, CO_2-SFE substitutes a petrochemical solvent (*e.g.*, hexane) to recover non-polar ingredients. It is a technology that operates at mild temperatures and can fractionate volatile and heavy components. Since it is a versatile technique, the extraction may run with CO_2 to yield solvent-free extracts or use co-solvents as polarity modifiers (*e.g.*, ethanol, vegetal oils, and water). Since all solvents are GRAS, and there is no hazardous residual, the waste biomass becomes a sub-product for downstream processes. As demonstrated for the brown macroalgae *D. polypodioides* and *U. pinnatifida* (Table 5), CO_2-SFE effectively recovers antioxidant extracts containing the carotenoid fucoxanthin. When using co-solvents (ethanol or water) to reduce the extraction polarity, the process favors the presence of total carotenoids and phenolics in extracts. By using ethanol, the cosmetic high-value bioactive compounds phloretin and (-)-epicatechin were recovered from the red macroalga *H. musciformis (Table 5)*. In addition, fatty acids, such as long-chain omega-3, had been extracted from the brown macroalga *S. japonica* using sunflower oil as a co-solvent *(Table 5)*. Once pure supercritical CO_2 extracts non-polar chemicals, high-value ingredients remain in the sub-product biomass. In this sense, a sequential process with PLE to recover these compounds may be an efficient strategy, as demonstrated for other renewable raw materials, such as turmeric (Osorio-Tobon *et al.*, 2014). The macroalgae *C. fragile*, *G. gracilaris*, *L. ochroleuca*, and *P. pavonica* macroalgae *(Table 5)* have extractable compounds by PLE, such as PUFA, pigments, and phenolic compounds. For the cosmetic industry, these ingredients may enable the claims of anti-inflammatory, anti-aging, anti-pollution, and photoprotector, among others, to their final products. As the last step of the MAB, SWE, MAE, and conventional extractions shall be the chosen techniques to extract the polysaccharides (PS) from the PLE biomass sub-product. Indeed, Dobrincic *et al.* (2021) and Saravana *et al.* (2018) demonstrated the technical feasibility of using MAE and SWE to extract functional PS from de-oiled brown macroalgae (Table 5).

Table 7. Definition of the Sustainable Development Goals (SDGs) of United Nations (U.N.) (United Nations, 2022), and how MABs can Contribute According to U.N. Targets and Indicators.

SDGs	**MABs contribution**
SDG 1: No Poverty: "End poverty in all its forms everywhere."	**MABs Contribution:** Responsible harvesting and cultivation of macroalgae may contribute to incomes > US$ 1.25 per capita per day.
SDG 2: Zero Hunger: "End hunger, achieve food security and improved nutrition and promote sustainable agriculture."	**MABs Contribution:** Indirect enhance of productivity in macroalgae farming. A MAB transforms 100% of the biomass into products, then less biomass is necessary, and the price of the raw material increase in a fairtrade business model, expanding the farmers' incomes.
SDG 3: Good Health and Well-Being: "Ensure healthy lives and promote well-being for all at all ages."	**MABs Contribution:** Macroalgae are source of bioactive compounds against neglected tropical diseases.
SDG 4: Quality Education: "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all."	**MABs Contribution:** From macroalgae harvesting or cultivation until extractions with green technologies, MABs need qualified technical professionals. In couple of years, women and men develop skills for a new sustainable industry.
SDG 5: Gender Equality: "Achieve gender equality and empower all women and girls."	**MABs Contribution:** All businesses aware to stakeholder interests must implement corporate governance, in which a guideline addresses different day-a-day aspects in a company, including gender equality practices.
SDG 6: Clear Water and Sanitation: "Ensure availability and sustainable management of water and sanitation for all."	**MABs Contribution:** In an IMTA alongside with macroalgae, the reduction of eutrophication is proven.

SDGs	MABs contribution
SDG 7: Afford Clean Energy: "Ensure access to affordable, reliable, sustainable and modern energy for all."	**Macroalgae Contribution:** Macroalgae can remediate polluted areas, e.g., contaminated with heavy metals. This biomass cannot be raw material for a MAB but is for energy production.
SDG 8: Decent Work and Economic Growth: "Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all."	**MABs Contribution:** Green technologies have high productivity and add value to commodities locally. It favors the development of technological local industry and mitigates the carbon footprint of the overseas/road transportation of commodities raw material.
SDG 9: Industry, Innovation, and Infrastructure: "Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation."	**MABs Contribution:** MABs can be highly technological, lean, and small-scale having the capability to increase the local gross domestic product.
SDG 10: Reduce Inequalities: "Reduce inequality within and among countries."	**MABs Contribution:** Increase of income per capita through a Fairtrade relationship. Local MABs may foster the replication of business model as the Association of Seaweed Farming in northeast Brazil. There, women are the key players for sustainable harvesting and cultivation of macroalgae and selling goods made of macroalgae.
SDG 11: Sustainable Cities and Communities: "Make cities and human settlements inclusive, safe, resilient and sustainable."	**MABs Contribution:** As a cultural and natural heritage, the macroalgae harvesting traces origins to ancient fishing traditions. Local MABs must allocate part of their profits to recover and preserve natural macroalgae beds as a long-term strategy of raw material supply.

SDGs	MABs contribution
SDG 12: Responsible Consumption and Production: “Ensure sustainable consumption and production patterns.”	**MABs Contribution:** The supply chain is sustainable. When macroalgae origin is an IMTA, MABs promote lower water footprint and reduce eutrophication issues related to the other commercial good.
SDG 13: Climate Action: “Take urgent action to combat climate change and its impacts.”	**MABs Contribution:** In a Circular Regenerative Economy MABs, are pivotal for reducing the carbon footprint.
SDG 14: Life Below Water: “Conserve and sustainably use the oceans, seas and marine resources for sustainable development.”	**MABs Contribution:** MABs reduce eutrophication and water and carbon footprint. With the implementation of a sustainable harvesting strategy, macroalgae provides shelter and food for ocean living organisms. Apart a MAB, macroalgae bioremediates polluted areas, and these biomasses can be raw material for energy production.

All the mentioned MABs processes seek to upcycle the macroalgae biomass in the zero-waste practice that favors the Circular Regenerative Economy and Blue Economy, allowing the macroalgae supply chain to attend to most of the 17 Sustainable Development Goals (SDGs) of the United Nations (Table 7). It illustrates that innovative MABs can contribute to climate change mitigation, local partnership promotion, and gender equality, among other social and economic benefits.

8 CONCLUSIONS

Here, we demonstrated how MABs with green technologies maximize the renewable macroalgae biomass use, yielding high-value ingredients for the cosmetic industry. In addition, beyond the technical viability of obtaining different potential cosmetic ingredients, this work showed the importance of testing them through international bodies' recommendations to speed the bench-to-market transition. Lastly, the macroalgae supply chain can be a viable and key source of renewable ingredients to promote a sustainable economy and attend most of the 17 SDGs of the United Nations.

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6 CONSIDERAÇÕES FINAIS

Esse trabalho revelou, a partir de um levantamento bibliográfico, como as tecnologias verdes podem potencializar o uso de biomassa macroalgas de modo sustentável, produzindo ingredientes de alto valor para a indústria cosmética. Além disso, ofereceu modos de técnicos para viabilizar a obtenção de diferentes potenciais ingredientes cosméticos.

Esse trabalho também mostrou a importância de testes recomendados por órgãos internacionais que podem ser inseridos nas pesquisas acadêmicas, de modo a acelerar a transição da bancada para o mercado. Por fim, a cadeia de abastecimento de macroalgas pode ser uma fonte viável e chave de ingredientes de categoria verde e renováveis para promover uma economia sustentável e atender a maioria das 17 diretrizes da ODS das Nações Unidas.

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