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REVIEW

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Nutraceutical benefits of brown macroalgae *Durvillaea antarctica:* a bibliometric review

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ABSTRACT

Durvillaea antarctica, commonly known as Cochayuyo in Chile and Bull kelp in southern New Zealand, is a brown macroalgae recognized for its notable nutritional value. This includes high omega-3 essential fatty acids, vitamins, and particularly dietary fiber. Furthermore, it is acknowledged as a nutraceutical due to its antioxidative, anti-inflammatory, anticancer, antiviral, and anti-diabetic properties. An emerging industrial application involves using it as a reinforcing material in active food packaging with antioxidant capabilities. A comprehensive analysis was conducted wherein the Scopus database was used to conduct the initial bibliometric investigation encompassing the years since 1979. The search yielded 198 documents published in English, comprising 182 articles, 6 conference papers, 4 reviews, 3 book chapters, 1 note, 1 letter, and 1 erratum. Chile and New Zealand notably demonstrated high productivity, contributing more than 70 documents each. The most contributing authors, institutions, and journals in the field were systematically recorded. *D. antarctica*, due to its mounting scientific significance, is readily accessible in the temperate waters of the Southern hemisphere, offering substantial health and societal advantages. Bibliometrics was employed to generate graphical representations and thoroughly examine the most frequently cited documents, author networks, collaborative interactions, and topic categorization. The keywords were organized into clusters, one focused on phylogenetics and three centered on chemistry and metabolism, the physiology of brown algae phaeophyta, and the marine ecosystem, macroalgae, and biogeography. The analysis also highlighted the top three countries contributing to research in this domain: Chile, New Zealand, and Australia. This bibliometric and nutraceutical investigation serves as compelling evidence supporting the myriad applications of *D. antarctica* biocultural value in food science and technology, offering valuable insights to inform policy decisions.

KEYWORDS

Bibliometrics; Bull kelp; Cochayuyo; *Durvillaea antarctica*; Nutraceutical

ARTICLE HISTORY

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Introduction

Durvillaea antarctica is the type species of the genus *Durvillaea* Bory de Saint-Vincent, 1825. *Durvillaea antarctica* (Chamisso) Hariot, 1892 is a brown macroalgae of the family Durvillaeaceae, phylum Gyrista, subphylum Ochrophytina, class Phaeophyceae and order Fucales [1]. This exclusive Southern Hemisphere (subantarctic islands and coasts of southern Chile and New Zealand) algae is an important foundation species for the local community structure of benthic organisms, including microbiota, and has a biocultural significance of economic value in food and habitat [2]. *Durvillaea* species have a cylindrical stipe fixed to a rocky substrate and need intertidal wave exposure [3]. The blades are the largest biomass attached to the stipes and have internal honeycomb anatomy causing buoyancy to the thalli, which are light to dark brown and olive-green. Artisanal harvesting is done by cutting the stipe, and regeneration after harvest varies. Chilean harvest of *D. antarctica* has increased since 2000 up to 39,000 Tons/year of this most consumed seaweed [4]. New Zealand has a seasonal harvest of this seaweed, considered a wild food [5]. Mass percentages of proximal analysis of Chilean D. antarctica blades (cited as leaves) were moisture 72.3 ± 1.5 g/100 g fresh macroalgae, and percentages of dry weight were ash 17.9 ± 1.2, protein 10.4 ± 0.3, lipid 0.8 ± 0.1, carbohydrate 70.9 ± 2.7, and dietary fiber 71.4 ± 0.5 g/100 g dried macroalgae (Ortiz et al., 2006).

In Chile, the brown macroalgae *D. antarctica* called Cochayuyo is considered a patrimonial food rich in alginate [6]. Biorefinery processes produce alginate from brown seaweed under conventional alkaline conditions to extract soluble sodium alginate [7]. Pōhā are traditional airtight storage Māori bags made of *D. antarctica* Bull kelp from New Zealand, used to carry and store food and fresh water for clothing and sports gear [8]. Figure 1 shows a fresh and dried *D. durvillaea* from New Zealand and Chile. Dried *D. antarctica*, is sold as Cochayuyo in Chilean local markets and supermarkets. It is a sea product Chileans are proud to consume stewed with potatoes, included in soups, salads, and more recently as vegetarian ceviche (P, Vit, personal

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Figure 1. Blades of *Durvillaea antarctica* macroalgae from the Southern Hemisphere. Fresh Bull kelp in New Zealand (left) Photo: © [10], and dried commercial Cochayuyo in Chile presented as whole thalli (center), and cut pieces (right) Photos: ©P Vit.

observation). Astorga-España et al. used Cochayuyo as an ingredient in popular Chilean dishes such as bread, hamburgers, huiro breadsticks, luche-parsley pesto, and fettuccine to promote the intake of this seaweed with nutritional benefits, especially increased fiber and polyunsaturated fatty acids (PUFAs) contents [9]. This Chilean marine macroalgae is a healthy choice for traditional culinary preparations with patrimonial value to connect social communities with their territory (Troncoso-Pantoja et al., 2019).

Seaweed use as raw material has economic significance in producing the hydro-colloids agar, carrageenan from red seaweed, and alginates from brown seaweed, which are used in food, cosmetics, medicine, and pharmacy [11]. Macroalgae contains a wide range of bioactive phytochemicals that show therapeutical potential. Species belonging to *Ochrophyta* synthesize a unique class of polyphenols known as phlorotannins, polymers of phloroglucinol (1,3,5-trihydroxybenzene) with unique linkages [12]. *D. antarctica* extract was added to plasticized polylactic acid (PLA) matrices with triethyl citrate (TEC) to produce antioxidant bio-nano composites for active food packaging. The solvent casting method obtained flexible and optically transparent films [13]. Macroalgae use in rainbow trout feeding increased the high-quality essential polyunsaturated fatty acids PUFAs lipid content in the flesh (Dantagnan et al. 2009). Four macroalgae from the Strait of Magellan Chilean coast including the D. antarctica, showed a high concentration of minerals and fiber, moderate protein, and a low lipid content (Astorga-España and Mansilla 2013). (Troncoso-Pantoja et al., 2019). Alginate are polysaccharide extracted from D. antarctica, promotes the growth of beneficial Bifidobacteria and inhibits pathogenic bacteria causing colonic fermentation. Bioactive phycopeptides such as phycobiliproteins, glycoproteins, phycolectins, and mycosporine-like amino acids, have functional properties beneficial to health that deserve attention by nutritional managers of metabolic syndrome (Guerrero-Wyss et al., 2023). A bibliometric study was conducted since the first article published on *Durvillaea antarctica* or its ethnic name in Chile Cochayuyo and in New Zealand Bull kelp, and the nutraceutical properties were reviewed.

Materials and Methods

Bibliometric study

Web of Science (WoS) and Scopus are the best scientific databases [14]. The supremacy of WoS found a competitor in Scopus [15]. Compared to WoS, a 20% higher coverage of documents is provided by Scopus [16]. Therefore, Scopus was chosen as the largest database available.

Scopus database

The bibliometric search was conducted in the Scopus database, in the "TITLE-ABS-KEY" field, on October 08, 2023. The operator AND was used for durvillaea AND antarctica, with the operator OR for Cochayuyo OR “bull kelp” of all documents using the following query string: TITLE-ABS-KEY (durvillaea AND antarctica OR cochayuyo OR “bull kelp”) AND PUBYEAR < 2024.

Bibliometrix statistical analysis and visualization

Bibliometric analyses were done with Bibliometrix, which is programmed in R, integrated with other statistical R-packages, and has constantly upgraded software [17]. Data collection from the Scopus database was extracted in a CSV Excel file, and statistical computing analysis and graphics were performed using the Biblioshiny interface. The most cited documents, one plot on multivariate analysis investigated correlations and classifications of authors' keywords with multivariate graphical tools for topical dendrograms by Hierarchical Cluster Analysis (HCA).

Results and Discussion

Bibliometric analysis and nutraceutical properties of *D. antarctica*, are presented in the results.

Bibliometric analysis of *D. antarctica* publications using the Scopus database

The Scopus database provided the sources of published research ranked for authors, institutions, countries, sources, subject areas, and funding sponsors, as well as the document

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type. The first document on Bull kelp was published by C.H. Hay [1]. The title was "Some Factors Affecting the Upper Limit of the Southern Bull Kelp *Durvillaea antarctica* (Chamisso) Hariot on two New Zealand shores", and the selected source was the Journal of the Royal Society of New Zealand [1]. From the 198 retrieved documents, 192 were in English, 4 in Spanish, and 2 in Chinese. They were categorized into topical algal subjects of biological activity, chemical composition, marine ecology, environmental chemistry, and physiology.

A total of 198 documents were retrieved for *Durvillaea antarctica* or cochayuyo or "bull kelp", 182 articles, 6 conference papers, 4 reviews, 3 book chapters, 1 erratum, 1 letter, and 1 note (Table 1). These documents were tabulated for the top ten rankings of classic metrics. If nutraceutical* is added to the search query, only two documents were extracted from the Scopus database. Nutraceuticals is a general term, not a frequent word for studies of particular biological activities. The 198 documents extracted from the Scopus database in comma-separated values (CSV) files were further visualized with the Bibliometrix software using selected plots. The time span of the main information of bibliometric descriptors comprised publications from the first retrieved document since 1979 to date in 2023. The bibliometric descriptors are presented in Table 1.

The *D. antarctica* document growth since 1979 has not been steady. There was a tendency to increase the number of documents until the year 2010 with 11, but it decreased to 3 in the year 2014, increased up to 16 in the year 2019, and a steady decrease was observed up to this year with 8 documents that may rise until the December 31, 2023. The top ten authors in Table 2 are from five universities in Chile and New Zealand, having 7 to 28 documents. J.M. Waters is the most prolific author besides C.I. Fraser, both from the University of Otago in New Zealand; M. Thiel and F.B. Tala from Universidad Católica del Norte, Chile, and D.R. Schiel from the University of Canterbury, New Zealand were the top five authors.

In Table 3, the top ten institutions were ranked with 12 to 47 documents, in Chile (6), New Zealand (3), and Australia (1).

Table 1. Bibliometric descriptors of published *Durvillaea antarctica* or Cochayuyo or Bull kelp research since 1979.

Bibliometric descriptor	Counts All documents
Time-span	1979:2023
Scopus Database	
Number of documents	198
Number of articles	182
Number of conference papers	6
Number of reviews	4
Number of book chapters	3
Number of erratums	1
Number of letters	1
Number of notes	1
Number of languages	3
Bibliometrics	
Annual growth rate (%)	1.59
Sources (No. journals, books)	100
Author's Keywords DE (No.)	633
Keywords Plus ID (No.)	1627
Average citations per document	31.32
Document average age (years)	11.9
Authors (No.)	552
Single-authored documents (No.)	8
Multi-authored documents (No.)	190
International co-authorship (%)	36.36
Average co-authors per document (No.)	4.44
References (Total No.)	10007

Table 2. Top-ten most productive researchers in *Durvillaea antarctica* or Cochayuyo or Bull kelp since 1979 with their affiliations and countries.

Ranking	NP[1]	*D. antarctica* or Cochayuyo or Bull kelp		
		Author	Affiliation, city	Country
1	28	Waters, J. M.	University of Otago, Dunedin	New Zealand
2	25	Fraser, C. I.	University of Otago, Dunedin	New Zealand
3	17	Thiel, M.	Universidad Católica del Norte, Antofagasta	Chile
4	14	Tala, F. B.	Universidad Católica del Norte, Antofagasta	Chile
5	13	Schiel, D. R.	University of Canterbury, Christchurch	New Zealand
6	12	Spencer, H. G.	University of Otago, Dunedin	New Zealand
7	11	Mansilla, A.	Universidad de Magallanes, Punta Arenas	Chile
8	10	Macaya, E. C.	Universidad de Concepcion, Biobio	Chile
9	9	Craw, D.	University of Otago, Dunedin	New Zealand
10	7	Hay, Cameron H.	University of Otago, Dunedin	New Zealand

[1]NP number of publications

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Table 3. Number of documents on *D. antarctica* or Cochayuyo or Bull kelp since 1979 ranking top ten most productive institutions worldwide.

Ranking	NP[1]	Institution	Country
1	47	University of Otago	New Zealand
2	25	University of Canterbury	New Zealand
3	22	Universidad Católica del Norte	Chile
4	20	Universidad Austral de Chile	Chile
5	18	Centro de Estudios Avanzados en Zonas Áridas CEAZA	Chile
6	16	Allan Wilson Centre for Molecular Ecology & Evolution	Chile
7	15	Universidad de Magallanes	Chile
8	14	Universidad de Concepcion	Chile
9	12	The Australian National University	Australia
10	12	National Institute of Water and Atmospheric Research	New Zealand

[1]NP number of publications

The ten most productive countries, ranked in Table 4 on *D. antarctica*, Cochayuyo, or Bull kelp since 1979, produced 5-82 documents each. Chile, New Zealand, the United States, Australia, and Canada were the top five countries.

Table 5 shows the top ten sources used by authors to publish their research on *D. antarctica* since 1979. Each of these journals hosted between 4 to 15 documents. The top five sources were: Journal of Applied Phycology, Marine Biology, Marine Ecology Progress Series, Journal of Phycology, and Journal of Experimental Marine Biology and Ecology. Molecular Ecology and Carbohydrate Polymers are next, indicating a major preference on research topics. These are very good journals. Their h index varied between 63 and 251, 7/10 are Quartile 1, and the maximum impact score reached 11.93 for Carbohydrate Polymers, the highest h index. This is the best journal in the top ten, although it ranked 7th for this dataset.

The funding sponsors interested in supporting research on *D. antarctica* or Cochayuyo or Bull kelp since 1979 were ranked in Table 6. According to the number of publications that informed their financial support. The top five funding sponsors were Fondo Nacional de Desarrollo Científico y Tecnológico, Chile (26 docs), Comisión Nacional de Investigación Científica y Tecnológica, Chile (9 docs), University of Otago, New Zealand (8 docs), Royal Society Te Apārangi, New Zealand (7), and Australian Research Council, Australia (5).

Table 4. Number of documents in the ten countries most productive on *Durvillaea antarctica* or Cochayuyo or Bull kelp research since 1979.

Ranking	Country	NP[1]
1	Chile	82
2	New Zealand	74
3	United States	37
4	Australia	12
5	Canada	11
6	Spain	10
7	China	9
8	Germany	8
9	United Kingdom	5
10	Denmark	5

[1]NP number of publications

Table 5. Most productive journals hosting research of *Durvillaea antarctica* or Cochayuyo or Bull kelp since 1979.

Ranking	*D. antarctica* or Cochayuyo or Bull kelp Source (h index, Quartile, impact score)[1]	NP[2]
1	Journal of Applied Phycology (h 127, Q2, 3.56)	15
2	Marine Biology (h 129, Q2, 2.25)	11
3	Marine Ecology Progress Series (h 206, Q1, 2.55)	9
4	Journal of Phycology (h 137, Q1, 3.09)	8
5	Journal of Experimental Marine Biology and Ecology (h 137, Q21, 2.18)	8
6	Molecular Ecology (h 246, Q1, 4.89)	6
7	Carbohydrate Polymers (h 251, Q1, 11.93)	6
8	Botanica Marina (h 63, Q2, 2.19)	5
9	Journal of Biogeography (h 169, Q1, 3.91)	4
10	Algal Research (h 88, Q1, 5.52)	4

[1]https://www.resurchify.com; [2]NP number of publications

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Table 6. Most supportive funding sponsors on research projects on *Durvillaea antarctica* or Cochayuyo or Bull kelp since 1979.

Ranking	Funding sponsor	Country	NP[1]
1	Fondo Nacional de Desarrollo Científico y Tecnológico	Chile	26
2	Comisión Nacional de Investigación Científica y Tecnológica	Chile	9
3	University of Otago	New Zealand	8
4	Royal Society Te Apārangi	New Zealand	7
5	Australian Research Council	Australia	5
6	Fondo Nacional de Desarrollo Científico, Tecnológico y de Innovación Tecnológica	Perú	4
7	Foundation for Research, Science and Technology	New Zealand	4
8	Marsden Fund	New Zealand	4
9	Ministry of Business, Innovation and Employment	New Zealand	4
10	National Institute of Water and Atmospheric Research	New Zealand	4

[1]NP number of publications

D. antarctica, Cochayuyo, or Bull kelp published research since 1979, mostly on Agricultural and Biological Sciences, for 45.2% of the documents. The following Scopus subject areas of interest were Environmental Science (15.3%), Earth and Planet (7.8%), Biochemistry, Genetics and Molecular Biology (7.2%), and Chemistry (6.3%) as the top five.

Visualization of *D. antarctica* publications since 1979 using bibliometrics

Selected Bibliometrics techniques were used to visualize plots using authors' keywords, co-authors' collaborative networks and country collaborative map, and the conceptual structure for the highest contributions and most cited documents.

Authors' keywords: most relevant words, dendrogram, thematic evolution map

In Figure 2, a word cloud plot was based on author's keywords in *D. antarctica* documents since 1979 in frequency order from 8 to 118 occurrences. The frequency of author's keywords is weighed using different colors, positions and discriminating their corresponding size. The highlighted keywords in this plot were seaweed (56), algae (53), kelp (47), chile (45), new zealand (37), and brown alga (34); followed by the secondary impact of phaeophyceae (28), durvillaea (25), macroalga (25), macrocystis pyrifera (25), ecosystem (24), phylogeny (24), dispersal (21), kelp forest (19), pacific ocean (16), alga (15),

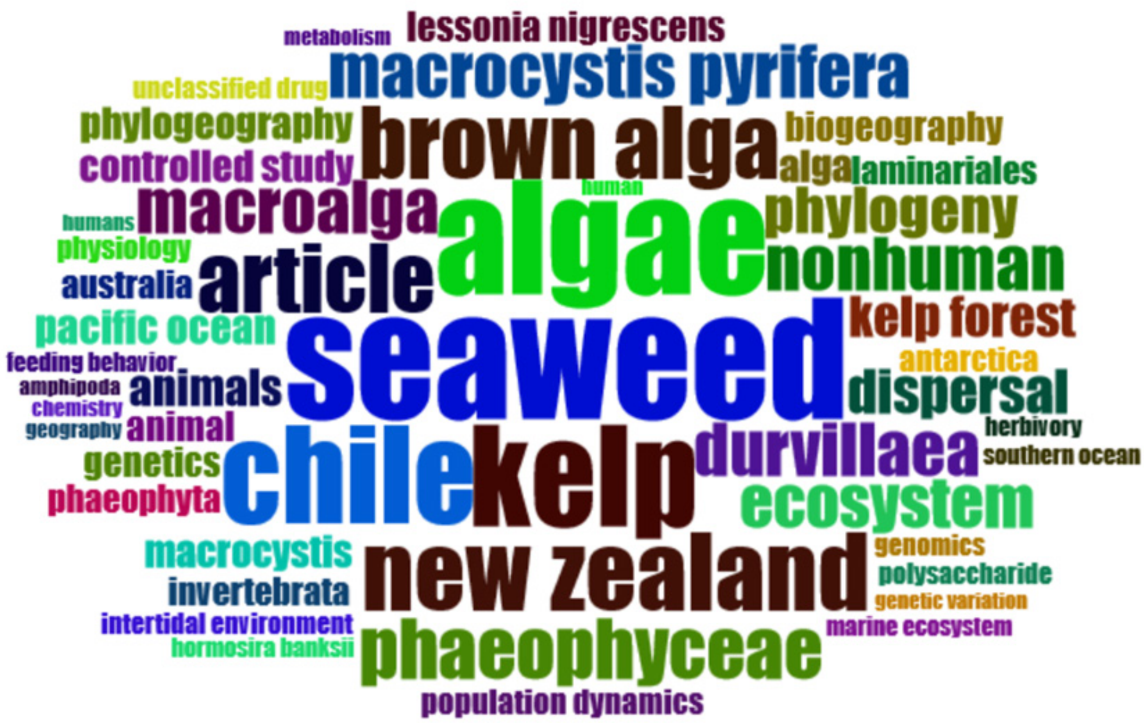

Figure 2. Word cloud using authors' keywords in the scientific literature of *Durvillaea antarctica* since 1979.

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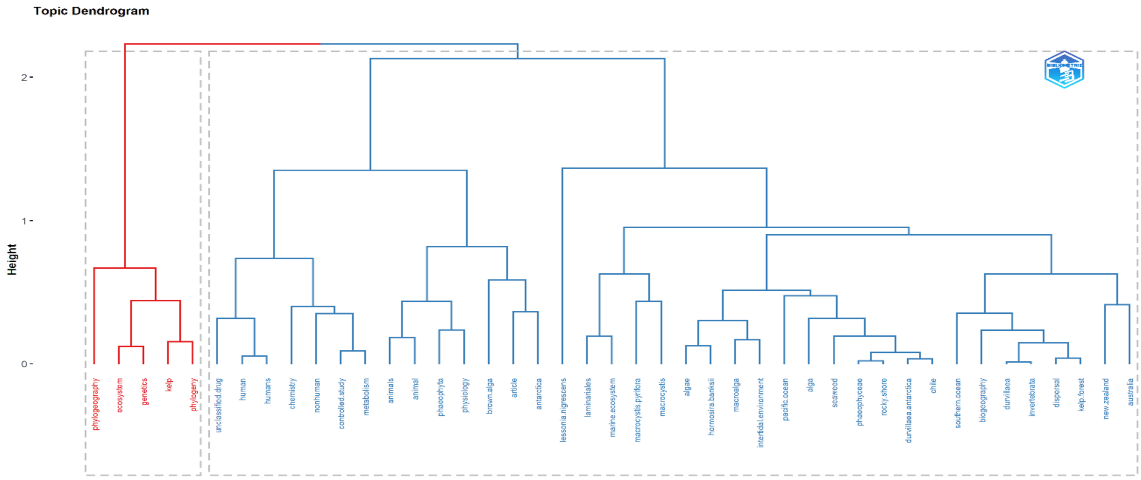

Figure 3. Topic dendrogram by HCA of authors' keywords in *Durvillaea antarctica* publications since 1979. The suggested topics for the red cluster was on phylogenetics, and for the blue cluster were visualized chemistry and metabolism, physiology of brown algae phaeophyta, and a large subcluster for marine ecosystem, macroalgae, biogeography, and the top-3 countries Chile, New Zealand, and Australia.

macrocystis (15), phylogeography (15), biogeography (14), genetics (14), lessonia nigrescens (14), australia (13), invertebrate, laminariales (13), phaeophyta (13), and antarctica (12), to mention about half of the keywords used by authors in their publications (Figure 3).

Co-authors collaborative networks and country collaborative map

The collaborative networks of co-authors were grouped in the eight clusters of research groups identified in Figure 4. Cluster 1 (red) with six co-authors from New Zealand, cluster 2 (blue) included 14 nodes with co-authors from Chile, cluster 3 (green) with three nodes from Chile, cluster 4 (lilac) with two co-authors from Australia, cluster 5 (orange) with two nodes for co-authors from Australia, Cluster 6 (brown) with six nodes, one co-author from Denmark, and five from New Zealand, cluster 7 (pink) with two large nodes for Fraser ci and waters jm in a total of nine co-authors, one from Australia and eight from New Zealand, including hay ch, the author of the first publication on *D. antarctica* in 1979, cluster 8 (grey) with three nodes from Chile, and cluster 9 (light green) with two nodes from Chile [1,2].

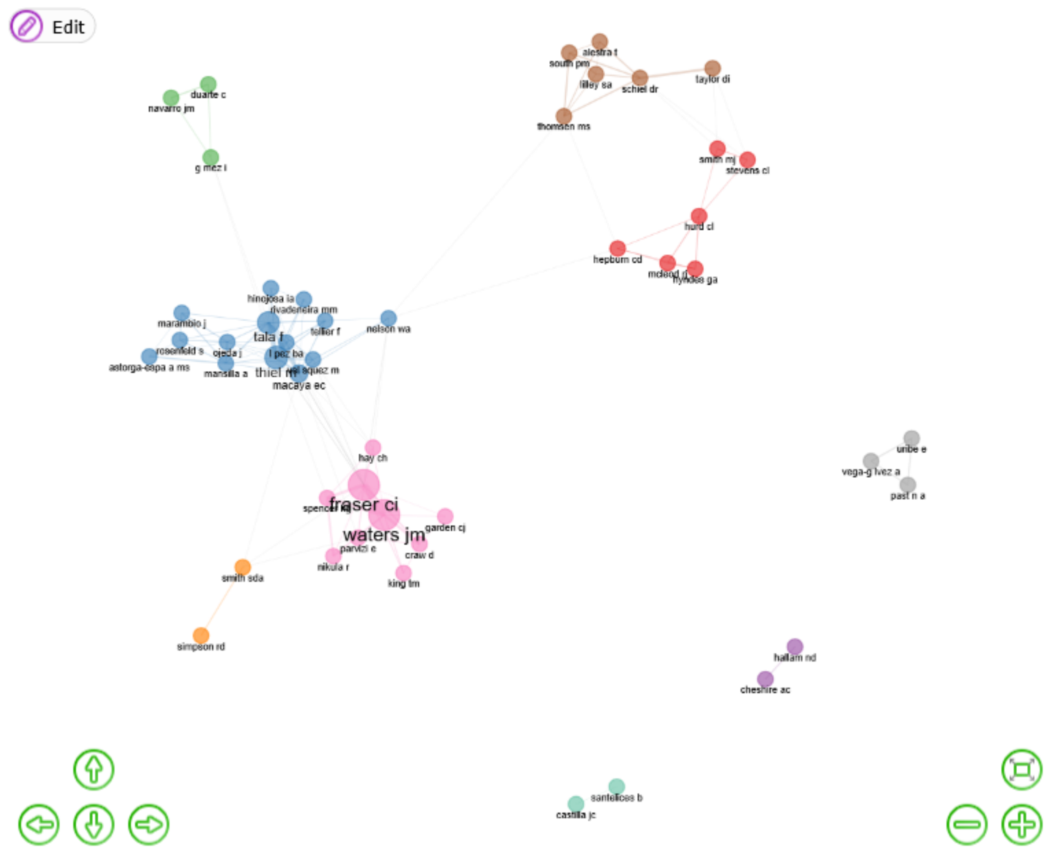

Figure 4. Collaborative networking of *Durvillaea antarctica* researchers since 1979.

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The collaboration between countries was visualized with red connectors in a worldwide map between countries sharing publications on *D. antarctica* or Cochayuyo or Bull kelp since 1979 in Figure 5. The frequencies of collaboration between two countries were extracted in an Excell file. The highest collaborative frequency (17) was between New Zealand and Australia, (9) between Chile and Spain, (5) between Chile and Australia, Chile and Germany, Chile and New Zealand, (4) between Chile and Canada, Chile and Germany, New Zealand and Canada, and (3) Chile and United Kingdom, New Zealand and Germany. A red line between countries is plotted for three or more shared documents. Therefore, countries sharing one or two publications are not connected with red lines in Figure 5. The two thickest connectors in the worldwide collaborative map were between New Zealand and Australia, and between Chile and Spain, indicating the prolific collaborative research between researchers of these countries.

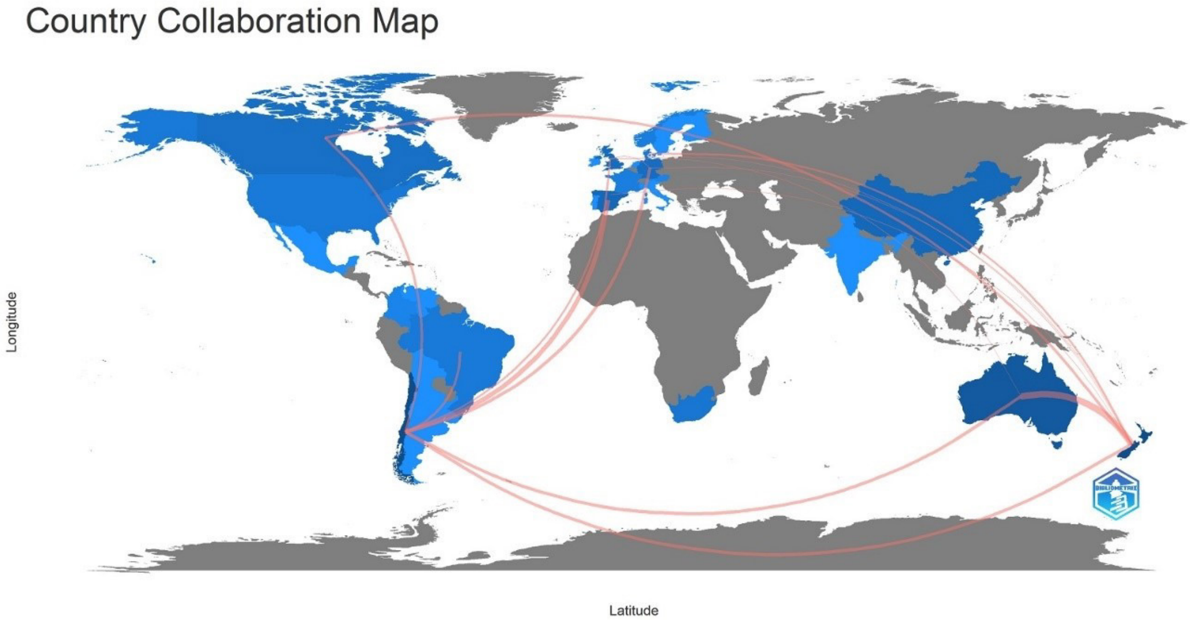

Figure 5. World map with country collaboration for *Durvillaea antarctica* documents since 1979. Higher productivity is for dark blue than light blue countries. Red lines represent collaborative rates. Connecting countries increases line thickness with the most frequently shared publications.

The conceptual structure for highest contributions and most cited documents

The top ten publications on *D. antarctica* with the highest contributions since 1979 were visualized in a factorial map of two clusters (Figure 6) estimated based on closeness via the Correspondence Analysis (CA) multivariate statistical technique, considering the dimensions Authors' keywords, no. of documents per authors, and times cited (TC). The documents were categorized into two clusters across 2 dimensions or factors, with the highest contribution for the red cluster 1 documents positions in the positive quadrants.

The ten most cited documents on D. antarctica since 1979 were processed in a factorial map containing two clusters (Figure 7). The Fraser research group has four most cited documents, three in Cluster 2, two of them published in Molecular Ecology (2009, 2016), one in BMC Evolutionary Biology (2010), and one in Cluster 1 Proceedings of the National Academy of Science USA (2010). Nikula research group has two most cited documents, one in Marine Ecology Progressive Series (2010) Cluster 1 and one in Molecular Ecology (2009) cluster 2. From them, the articles with the highest global number of citations in Figure 7 were Ortiz J 2006 Food Chem (399), Fraser Ci 2009 Proc Natl Acad Sci USA (231), and Vergara Fernandez A 2008 Biomass Bioenergy (226) [18,21,22].

The most globally cited documents are illustrated in Figure 8. They were cited from 110 to 399 times in publications of *D. antarctica*, Cochayuyo, or Bull kelp since 1979. These top ten cited documents were published in ten diverse sources from 1980 to 2019. The most cited article has almost double the citations than the second most cited. Ortiz et al. is the seminal work on *Durvillaea antarctica* nutritional composition, it was compared with the green macroalgae *Ulva lactuca* in the classic journal Food Chemistry [21]. Soluble, insoluble, and total dietary fiber, amino acid, fatty acid, tocopherol, and tocotrienol were the chemical components analyzed for the nutritional characterization.

A three-field plot was created to visualize the main items of three selected fields and how they are related through a Sankey diagram, showing the flow from one set of values to another. Graphically, the line width between items is proportional to the frequency of a node. Field tags are used on top of each column of the Bibliometrics three-field plots (Figure 9). In Figure 8, a three-field plot was obtained based on the title (TI_TM), the authors (AU), and the author's country (AU_CO) for 10 items. This plot depicts the proportion of words used in the titles of research topics for each author and its country. Chile was used in the titles of only three authors from Chile in the published affiliation. The genus *Durvillaea* was used in the titles of the ten authors in the plot.

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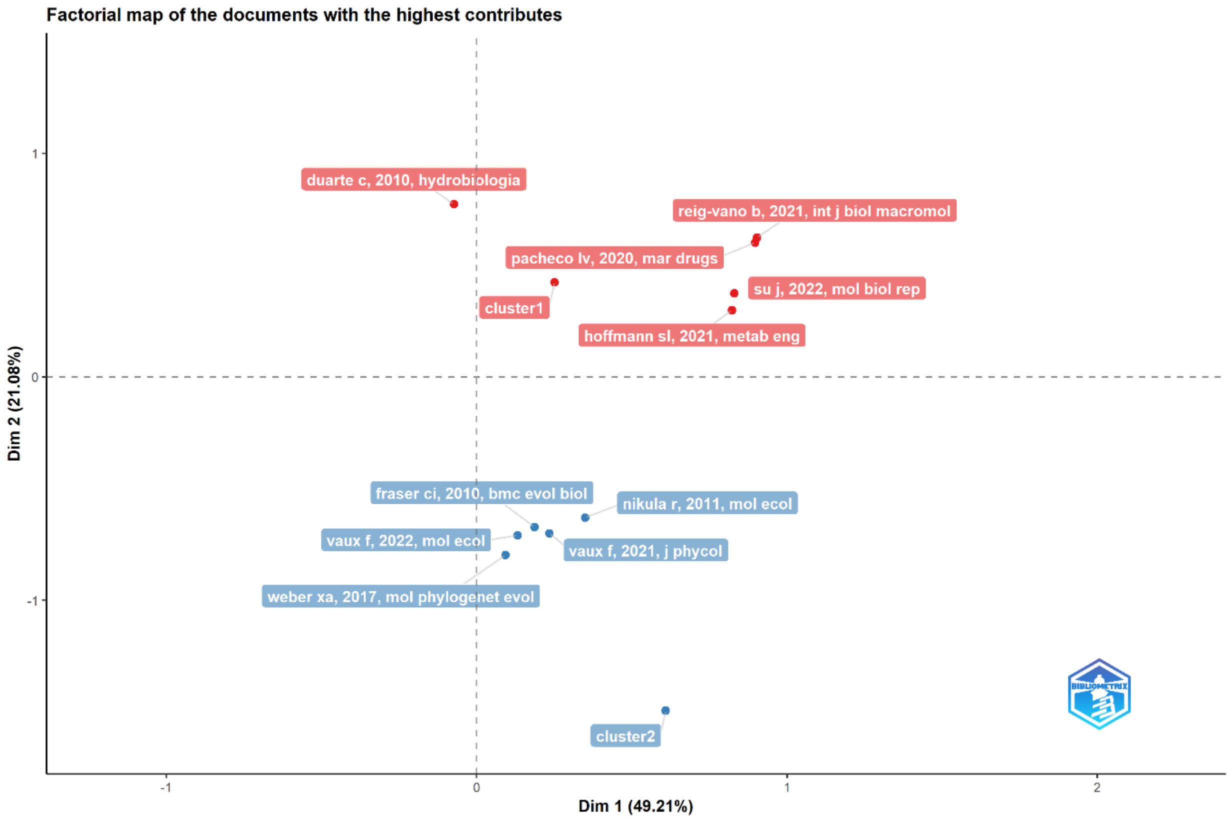

Figure 6. Factorial map of the *Durvillaea antarctica* documents with highest contributions.

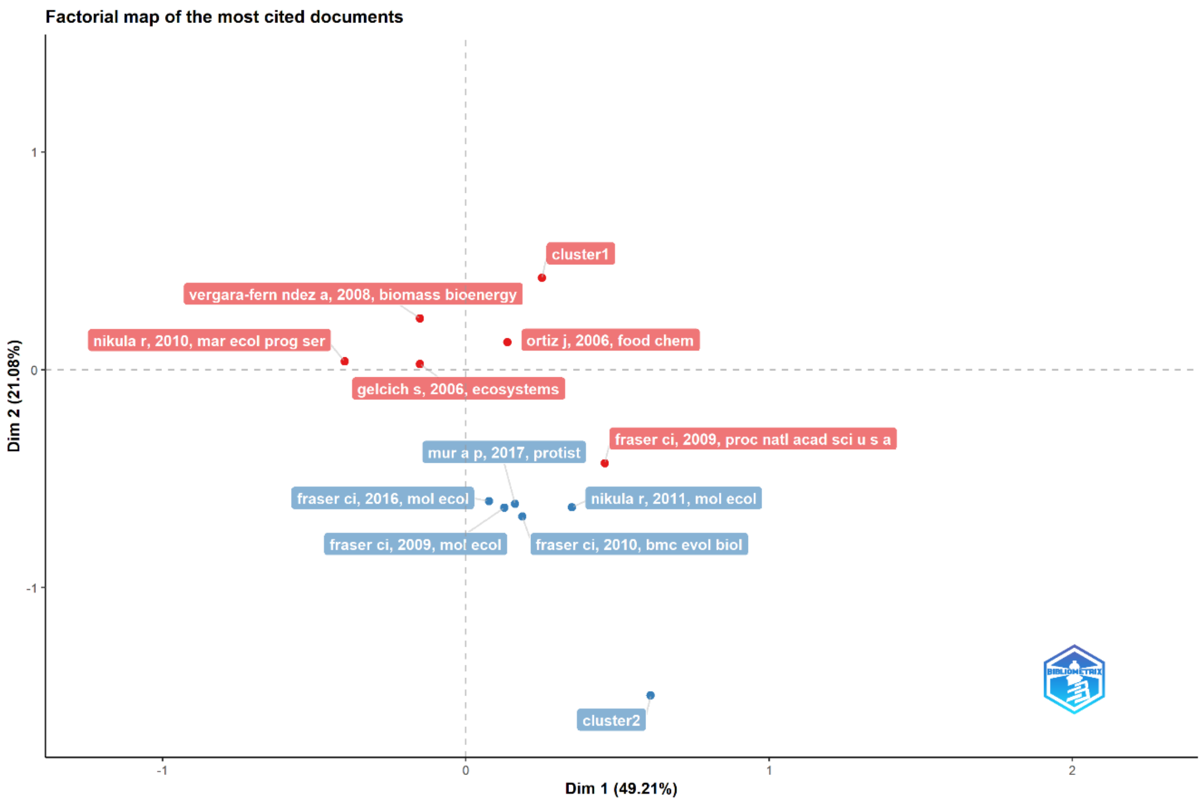

Figure 7. Factorial map of the most cited documents on *Durvillaea antarctica* since 1979.

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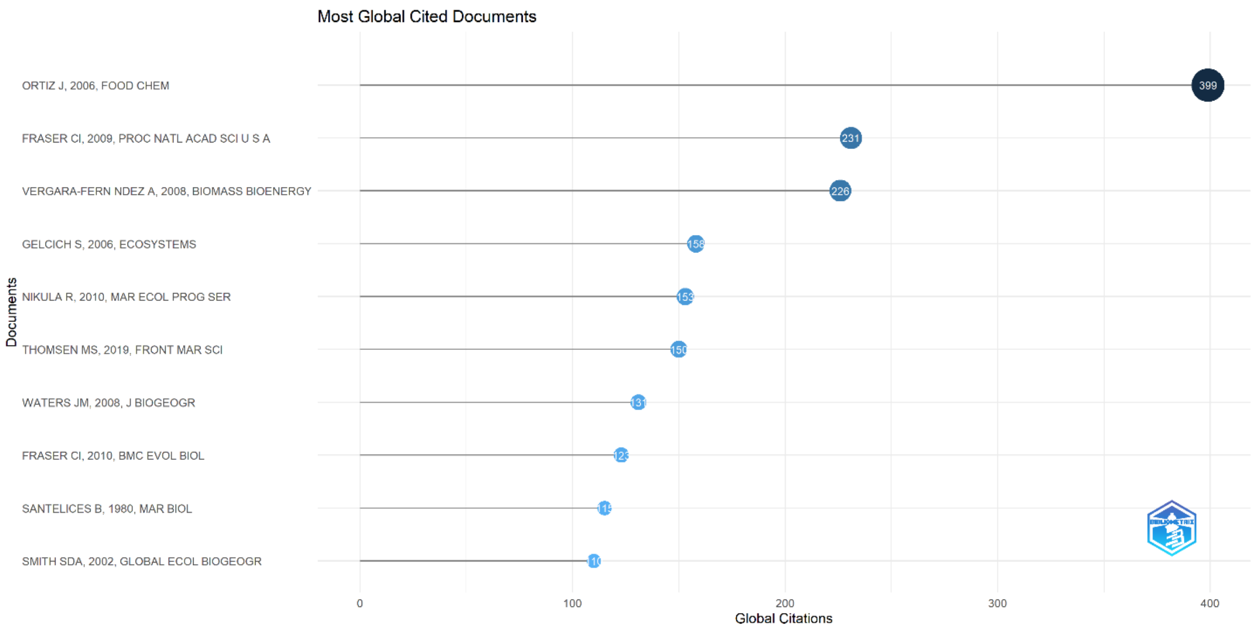

Figure 8. Most globally cited documents of *Durvillaea antarctica* since 1979.

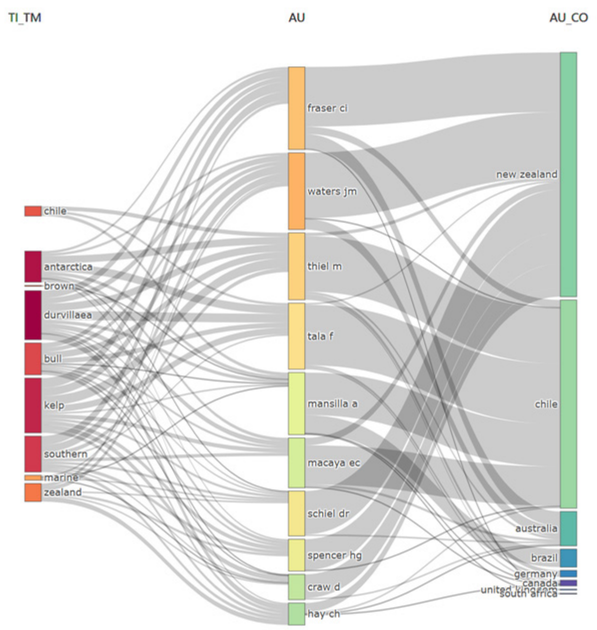

Figure 9. Three field plot of *Durvillaea antarctica* publications since 1979, Title (TI_TM), authors (AU), author's country (AU country).

Bioactive metabolites and nutraceutical properties of *D. antarctica*

Metabolites of nutraceutical value in *D. antarctica*

Bioactive metabolites comprise agar, aplysulphurin, fucoxanthin, β-1,3/1,6-glucan, phlorotannins, and α-tocopherol. The agar chemical structure and other metabolites are illustrated in Figure 10. The pigment fucoxanthin has an antioxidant effect and can reach up to 30% of the dry weight [23]. Fucoxanthin is dominant in brown seaweed, and eclipse other pigments like chlorophyll, carotenes, and xanthophylls. Phlorotannins are oligomers and polymers based on phloroglucinol (1,3,5-trihydroxybenzene), they are antioxidants.

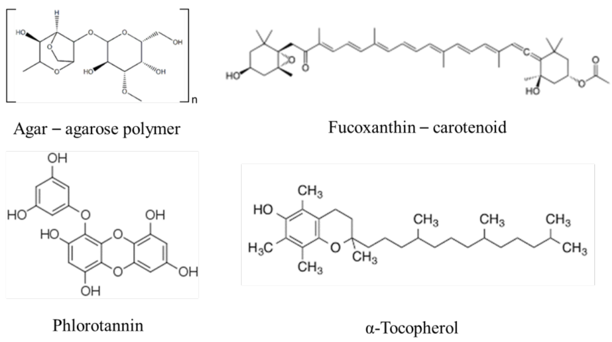

Figure 10. Metabolites of *Durvillaea antarctica*.

Biological activity

D. antarctica, exhibits various biological activities. One notable property is its anti-hypertensive effect, attributed to the presence of peptides within *D. antarctica* that inhibit the angiotensin-converting enzyme, resulting in hypotensive effects. Additionally, *D. antarctica* demonstrates anti-metabolic syndrome effects by inhibiting digestive enzymes, such as α-amylase and α-glucosidase. Specifically, three enzyme hydrolysates, Dur-A, Dur-B, and Dur-C, along with acarbose, were found to inhibit these enzymes, with inhibitory percentages of 53.3%, 69.8%, and 61.6%, respectively [24]. Furthermore, *D. antarctica* exhibited pancreatic lipase inhibitory activity, with Dur-A, Dur-B, and Dur-C showing inhibitory percentages of 38.1%, 33.6%, and 17.1% at a concentration of 0.3 mg/mL. These inhibitory effects on key metabolic enzymes contribute to the reduction of metabolic syndrome's impact on human health. The antioxidant properties of the macroalgae are attributed to its fucose-containing sulfated polysaccharide. These antioxidant activities were measured through various methods, including DPPH, ABTS, and ferrous ion-chelating assays [24]. Phyco-antioxidants, like those found in *D. antarctica*, hold potential for sustainable pharmaceutical applications [23].

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In cancer research, a β-1,3/1,6-glucan derived from *D. antarctica* has demonstrated antitumoral effects. It delayed tumor progression in various models, such as DLD1 xenograft, AOM-DSS-induced tumor models, and the PD-1 antibody in B16 syngeneic tumor model. This effect was achieved through increased macrophage phagocytosis and enhanced cytokine/chemokine secretion [25]. *D. antarctica* has also shown promise as an antiviral agent. Aqueous extracts of *D. antarctica* displayed antiviral activity against herpes simplex viruses (HSV-1 and HSV-2), providing a potential alternative to nucleoside analogs for treating these infections [26]. Furthermore, *D. antarctica* has been investigated for its blood-protective properties. A novel fucoidan extracted from this macroalgae promoted leukocyte growth in a mouse model, potentially by regulating bone marrow hematopoiesis. This suggests its potential as an antineoplastic agent for chemotherapy-induced leukopenia [27]. Enzymatic extracts of *D. antarctica*, containing phlorotannins and carbohydrates, have been found to exhibit higher angiotensin I-converting enzyme (ACE) inhibitory activity compared to maceration extracts. This suggests their potential as natural ACE inhibitors [28].

D. antarctica serves as a potential prebiotic, positively modulating gut microbiota. This modulation is associated with various health benefits, including anti-obesity, anti-inflammatory, anticancer, lipid-lowering, and hypoglycemic effects [29]. Furthermore, low molecular weight polysaccharides from *D. antarctica* have been identified as immunomodulators, with the potential to stimulate the immune system [30]. The sulphated polysaccharide 4 of D. antarctica (DAP4) immunomodulatory activity in vitro enhanced lymphocyte proliferation, increased macrophage phagocytic activity, NO production, and NK cell cytotoxicity, and was non-toxic to RAW264.7 cells at concentrations of up to 400 μg/mL (Qin et al., 2022). β-glucans bind to specific receptors on immune cells, trigger immune responses, and modulate the immune system (Singh and Bhardwaj, 2023). The algae also demonstrate UVB-photoprotective activity. In a study using a zebrafish embryo model, phenolic extracts of this macroalgae protected against UVB damage, with a 26.3% reduction in damage when compared to controls. Other macroalgae like *Macrocysta porifera* and *Porphyra columbina* showed even greater photoprotective effects [31].

Conclusions

This review on bibliometrics and advancing proposals of the potential nutraceutical benefits of the Phaeophyceae class brown macroalgae *D. antarctica* updated the state-of-the-art on scientific publications since 1979. Chile and New Zealand were the major producers of *D. antarctica* and also led the scientific productivity as authors, institutions, countries and funding agencies. Remarkable beneficial properties for human health of *D. antarctica* comprise anti-hypertensive, anti-metabolic syndrome effects, antitumoral, antiviral, blood protector, cardiometabolic, gut microbiota modulator, immune modulator, and UVB-photoprotective activity. Metabolites of *D. antarctica* are a marine source for replacing synthetic by natural compounds in the pharmaceutical industry. The combined bibliometric and nutraceutical review of D. antarctica applications in health science and food science, technological developments, and biocultural value provide evidence of pharmaceutical potential and territorial impact of patrimonial heritage to be considered by policy makers.

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